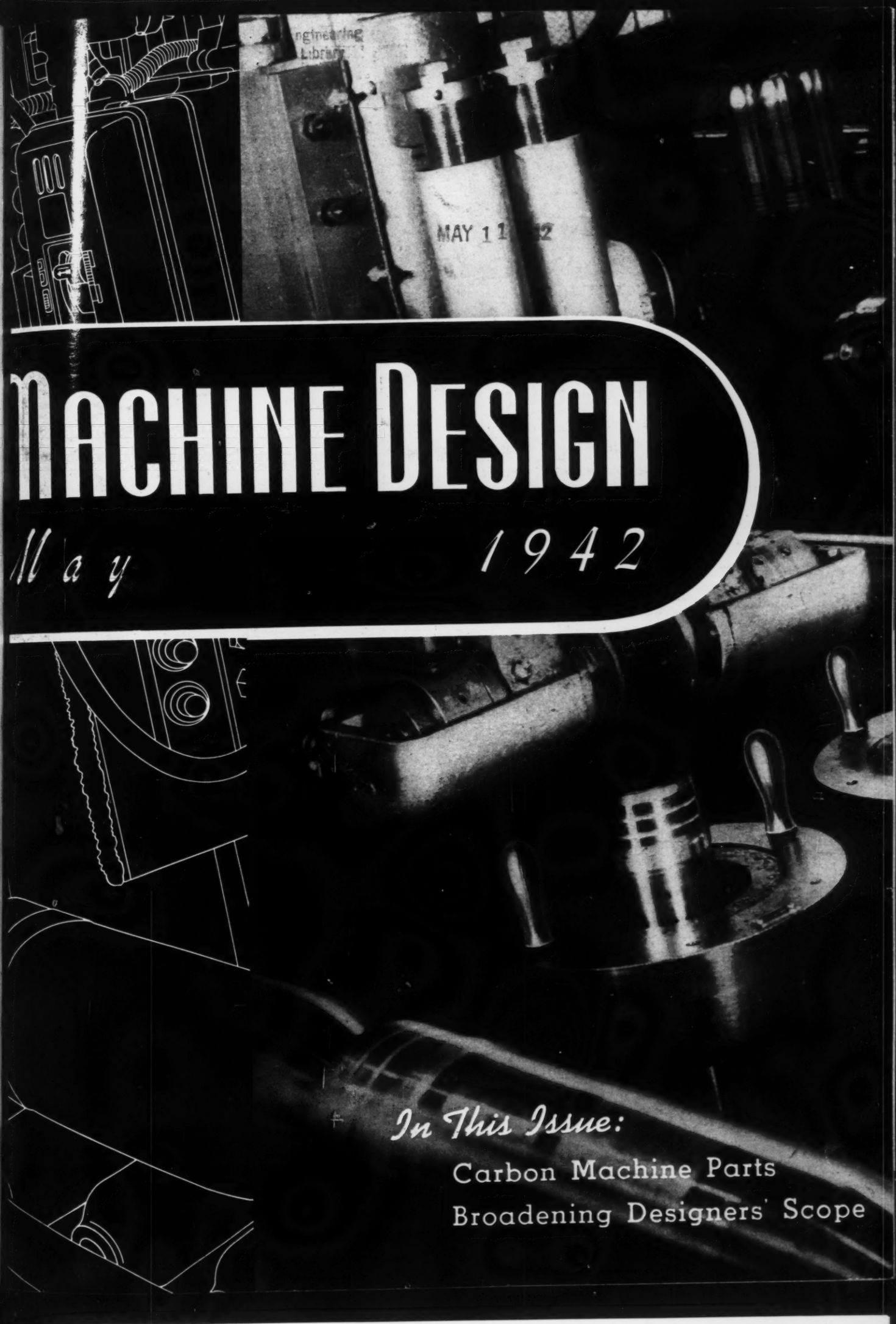
MAY 11
MACHINE DESIGN
May 1942
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Carbon Machine Parts
Broadening Designers' Scope

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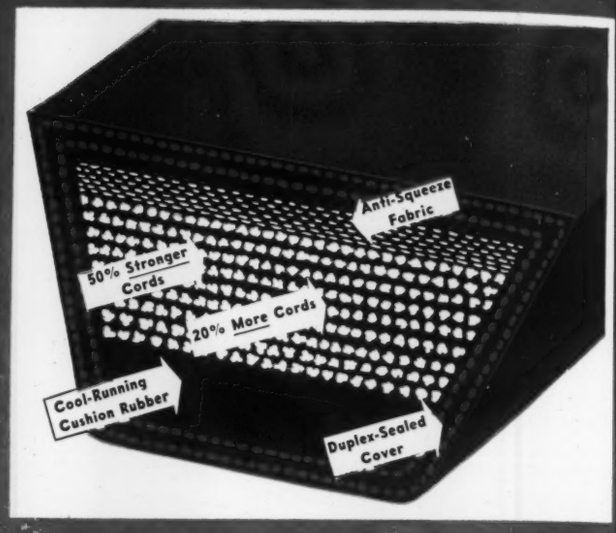
THREE LIFETIMES IN ONE!

1 50% STRONGER CORDS! Sensational new Flexon process makes cords 50% stronger than even those in former great Texrope belts.

2 20% MORE CORDS! Count them! You get 20% more of these tough, extra pulling power cords in every Texrope Super-7.

3 INCREASED LIFE! Cords float on amazing cool-running cushion rubber that absorbs shock . . . actually increases belt life phenomenally.

4 EXTRA PROTECTION! Exclusive duplex-sealed cover protects pulling cords against dirt, grit, moisture, and other adverse elements.



ALL THEY used to ask of power transmission was one-shift-a-day . . .

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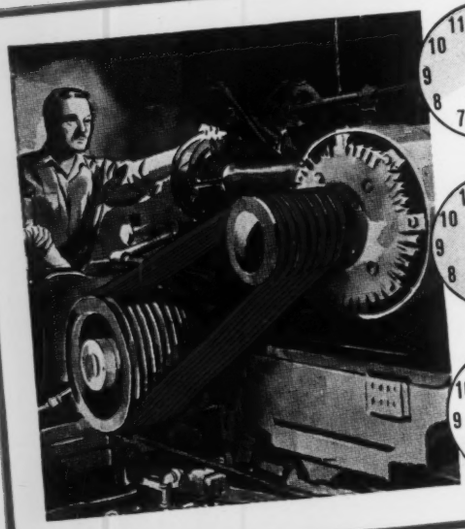

8 to 4 SHIFT!
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MACHINE DESIGN

THE PROFESSIONAL JOURNAL OF CHIEF ENGINEERS AND DESIGNERS

Volume 14 MAY, 1942 Number 5

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MAIN OFFICE: The Penton Publishing Co., Penton Bldg., Cleveland, O.

BRANCH OFFICES: *New York,* 110 East 42nd St.; *Chicago,* 520 N. Michigan Ave.; *Pittsburgh,* Koppers Bldg.; *Detroit,* 6560 Cass Ave.; *Washington,* National Press Bldg.; *San Francisco,* 1100 Norwood Ave.; *London,* 2 Caxton St., Westminster, S.W.1

PUBLISHED BY The Penton Publishing Co. E. L. Shaner, Pres. and Treas.; G. O. Hays, Vice Pres.; F. G. Steinebach, Secy. Published on seventh of month. Subscription in U.S. and possessions, Canada, Cuba, Mexico, Central and South America: Two years, $10; one year, $6. Single copies, 50 cents. Other countries: Two years, $14; one year, $8.

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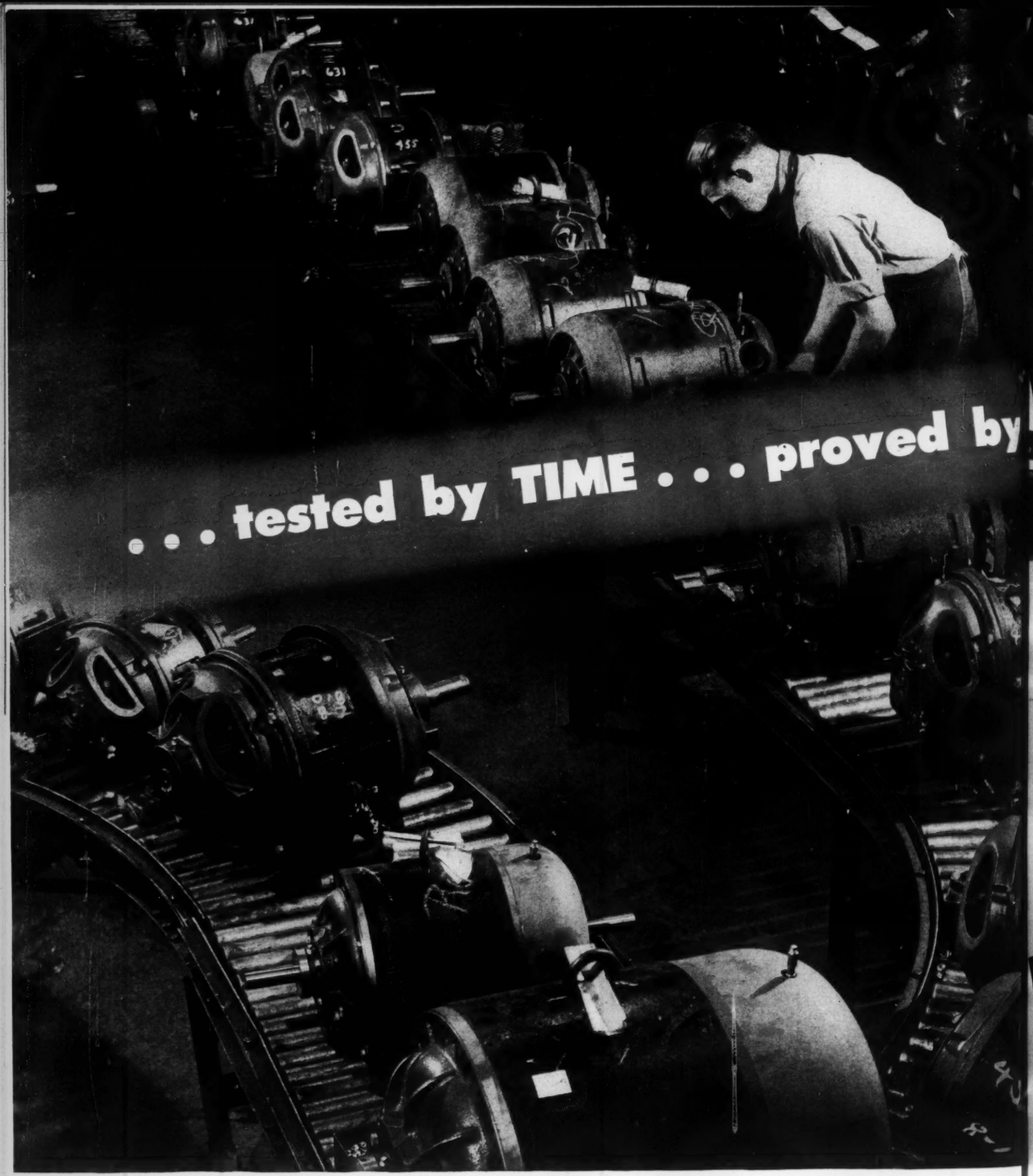

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DESIGN and development of machine tools that will simplify the processes of airplane fabrication to meet the shortage of skilled technicians is urged by George Hastings, personnel director of Vultee Aircraft, Inc. The necessity of quadrupling America's aircraft production schedule to meet the Axis production will make essential the employment of more and more unskilled and semi-skilled personnel in the industry. Only through simplification of processes will this be possible.

♦

FEMININE touch in war-time industry is proving adept in the drafting rooms as well as in assembly and other manufacturing operations. Adaptability of female workers to precision tasks prompted the Goodyear Tire and Rubber Co. to inaugurate two women's training classes, one for junior draftsmen and the other for sheet-metal workers. Initial class for junior draftsmen will be given three months of class work and training by observation in the company's aircraft drafting rooms. The course covers five eight-hour days per week. Aircraft terminology, drafting room procedure, shop processing, descriptive geometry, trigonometry, lettering and drafting room practice will be studied.

♦

VARIOUS types of nylon in solution have been used on a limited basis to coat wire for insulation in motors and other electrical units. All forms of synthetic insulation are receiving increasing attention both because of rubber shortages and limitations of rubber such as aging and low resistance to attack by oil.

♦

FORD has patented a new combined auto body and chassis welded from steel tubes, utilizing plastics for panels in doors, hood, roof, and sides. Principle difference from previous designs of tubular construction includes transverse cross members beneath each end of the body. Continuous tubes rise from the cross members to the car roof, forming the four corner posts, then running diagonally across to support the roof. This construction prevents transfer of torsion to the plastic panels and allows use of light-weight panels without weakening the body.

♦

INCREASED importance of dolomite in the national defense program as a source of magnesium and of furnace linings has resulted in a Bureau of Mines pamphlet on this subject.

♦

FINE-GRAINED phosphate coating for sheet steel has been developed to the point where it is processed by passing through a series of operations on rubber rollers, making production entirely automatic from feeding to packing the finished sheet. Developed by Parker Rust-Proof Co. and called Bonderite "K", production capacity now on order will coat over 2¼ billion square feet of sheet annually. This will release several thousand long tons of tin for more vital war production. The coating produces a rust-inhibiting steel "black plate" which when lacquered or enameled is successfully used in bending, drawing, crimping, lock-seaming and other forming operations required in the manufacture of cans, bottle caps and containers.

♦

SPEAKING of the Ford Bomber plant, Senator Harry S. Truman says, "The Willow Run plant is incomparable. For the first time, sufficient orders have been placed so that a manufacturer could establish a high-speed plant for the production of a single type of craft. Nothing was more impressive than to be informed that the current bomber production in this country now exceeds the former manufacturing effort of the combined auto industries of the nation."

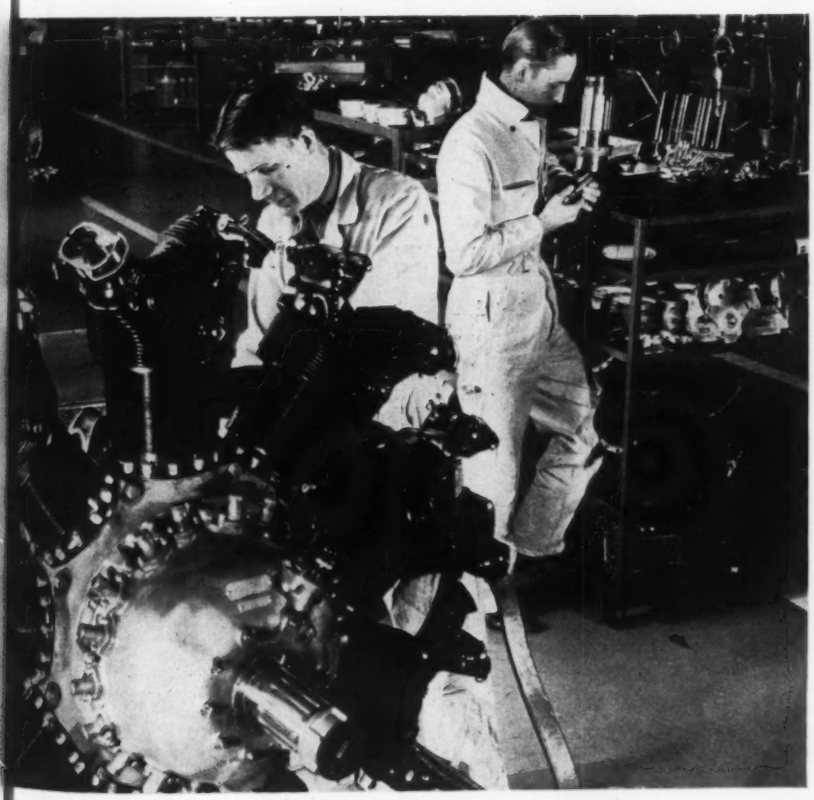
♦

ECONOMIES of built-in-reflector lamps through saving of critical material otherwise used for reflectors are being extended to infrared lamp bulbs for heating applications. Another saving of aluminum for reflectors is the return to silvered glass units for industrial lighting. Although fragile, the plated glass makes an excellent substitute.

MACHINE DESIGN

War Broadens Scope of Designers

By Kenneth D. Moslander



EVEN as the machine tool today is more than a machine tool—has become an instrument of destruction, a weapon for victory — so too is the machine designer more than a man who builds machines on paper. Never before has the designer been presented with a better chance to bring to bear all his potentialities for constructive engineering work. Those potentialities — resourcefulness, ingenuity, technical ability, experience —are being revitalized and regimented for the war effort.

A designer, in the past, may have designed adding machines. When he finished one design he started another, not very different from the last. Production problems were not primarily his. Problems of materials availability did not exist. The days when he was called upon to confront and solve a radically different engineering problem were few and far

between. He worked under specific direction and in accordance with carefully formulated plans.

Today all that is changed. As a nation we are calling upon all our material resources—many long dormant—that will assist in winning the war. The nation's demands upon the individual, upon the engineer, are not less exacting. New and more effective equipment as well as the development of existing machines are primary requirements. Production—mass production—is equally important.

What problems does this pose from the engineering standpoint? First, last and foremost is the squeezing out of every iota of the best war equipment possible with available facilities. Only when that has been done can the engineer rest on his laurels, confident of the result.

Production Increased by Standardization

To accomplish this increased production no rigorous formula of procedure exists. Each company and even each piece of equipment presents its peculiar problems. Many companies, like the machine tool manufacturers and airplane builders, find their most useful sphere in an extension and expansion of their normal activities.

In furtherance of the war effort, individual engineers are fulfilling a number of vital functions. Standardization is one. A careful examination may be conducted of a line of machines to determine which parts of one may be used in another. Usually it will not be that simple. A redesign of the part may be necessary to make it applicable to both machines. Advantages to be gained by such an organized standardization program may be tremendous. Retooling can be eliminated and idle machine time salvaged. Demand for skilled machinists to accomplish the tooling is alleviated. The burden on tool makers is lessened. Inventories that tie up critical materials are reduced. So, all along the line, production of parts is increased and vital resources in men and materials are released for other pressing war work.

Progressive Scarcity of Materials

Perhaps, however, the part is not one designed and made in the engineer's plant. Perhaps it is something like a ball bearing or a gear or a motor purchased from a supplier. The advantages of standardizing on the same bearing or gear or motor in a line of machines are no less vital to the war effort because such advantages accrue also to the supplier of these parts.

Another opportunity lies in the field of materials specifications. Today that usually means materials substitutions. Availability of materials is in a continual state of flux. Already history is the fact that scarcities of aluminum and zinc made imperative a substitute for die castings. Phenol resins were resorted to, resulting in their scarcity. Stampings were next, leading to shortages of killed and rimming steels—and so it goes.

Now plastic bonded plywood is coming into its own, opening up the whole field of the woodworking industry for war work. Engineers working with metals are inclined to look askance on wood as an engineering material. A comparison of the strength-weight ratios of these plywoods with aluminum and steel will yield the reason why this material is being considered for stressed members of military planes. Glass, silver, tile, concrete, iridium and thermoplastics are a few of the materials now amply available, with low carbon steel, bessemer steel, gray and malleable iron expected to be available shortly. Successful substitution by such materials calls for a type of ingenuity never before demanded of engineers. The reward for such success is an early victory.

While the machine tool industry is performing herculean feats in providing special machines for the mass production of military equipment there are a lot of standard machine tools lying idle for too many hours out of each twenty-four. Insofar as is humanly possible, designers are putting aside fancy ideas of designs requiring special machines and are investigating how far the operations schedule can be devoted exclusively to these idle lathes, millers and shapers. If it is possible, in this manner, to put to work such machines, a long forward step will have been taken. Parts will be made that will not be made while waiting for special machines.

Utilizing Machine Capacity

A second step is to get extra work for the idle machines. This may resolve itself into getting new contracts as a prime or sub contractor. If so, it ordinarily is out of the designer's field. However, there is no penalty for his thinking about it and doing something about it. In these days when every man is working under extreme pressure—when there just isn't time enough to do what has to be done—some things are bound to be overlooked. The engineer has usually lived with his plant a long time. He knows what's there and what can be done with it. This is not the time to say, "It's none of my business".

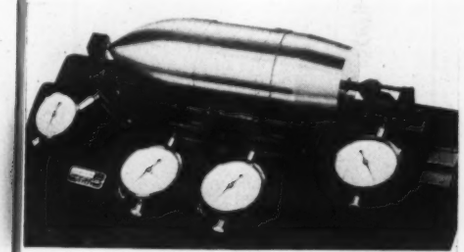
A lot is heard these days about tolerances. "That battery of old screw machines can't hold a dimension closer than ten thousandths of an inch," and fuse parts must be held to a fraction of that. The result is that the screw machines are collecting dust. What can be done about it? The first thing is that the war isn't being fought solely with fuses, or with breech mechanisms, or with any other single mechanism. Other parts may be suitable for production on these machines. That subject has been discussed in the foregoing. There is also another solution to the problem of these idle screw machines—rebuild them, making any design changes that may be essential.

(*Concluded on Page* 70)

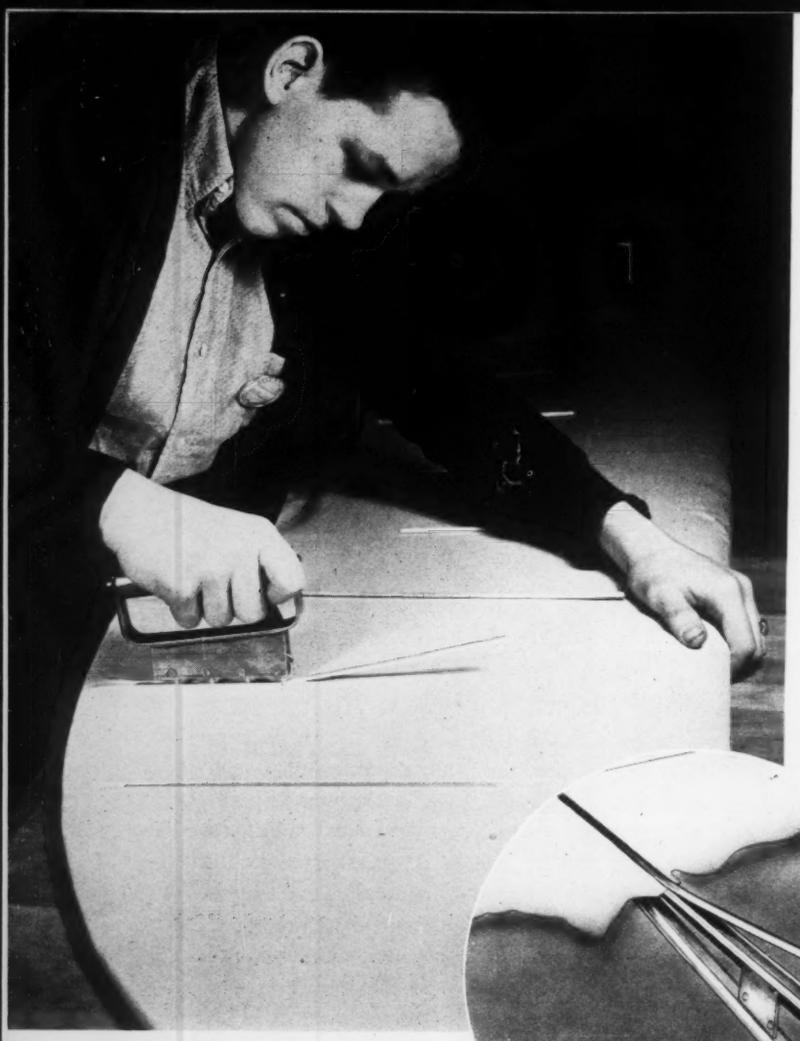
Scanning the field for IDEAS

Minute arcs in rapid succession etch case-hardened surfaces for identification of parts or for other purposes. Designed by the George Gorton Machine Co., etching is accomplished by a small tungsten electrode which is vibrated by a magnetic motor. Operating currents are as low as 12 amperes at 1.5 volts. Power is supplied from two transformers, one for the magnetic motor and the other for the etching current.

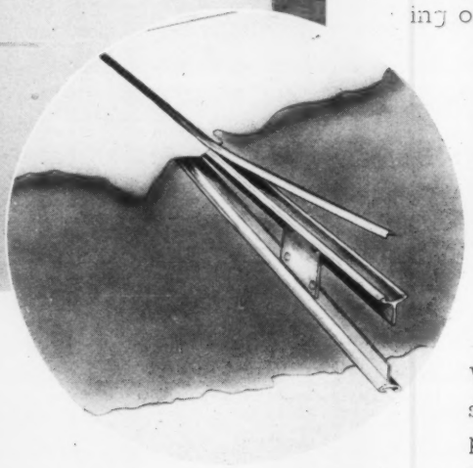
Each time the electrode is projected downward by the motor the workpiece is contacted, closing the etching circuit. Upon being withdrawn upward an arc occurs as the circuit is broken. Each arc causes a tiny crater to be formed in the workpiece due to the decomposition of the adjacent metal. A close succession of such overlapping marks or craters form the etch, the depth being determined by the amount of current and the width by the diameter of the electrode. The electrode floats on the workpiece to permit etching over undulating surfaces. This also permits automatic feeding to compensate for electrode wear.



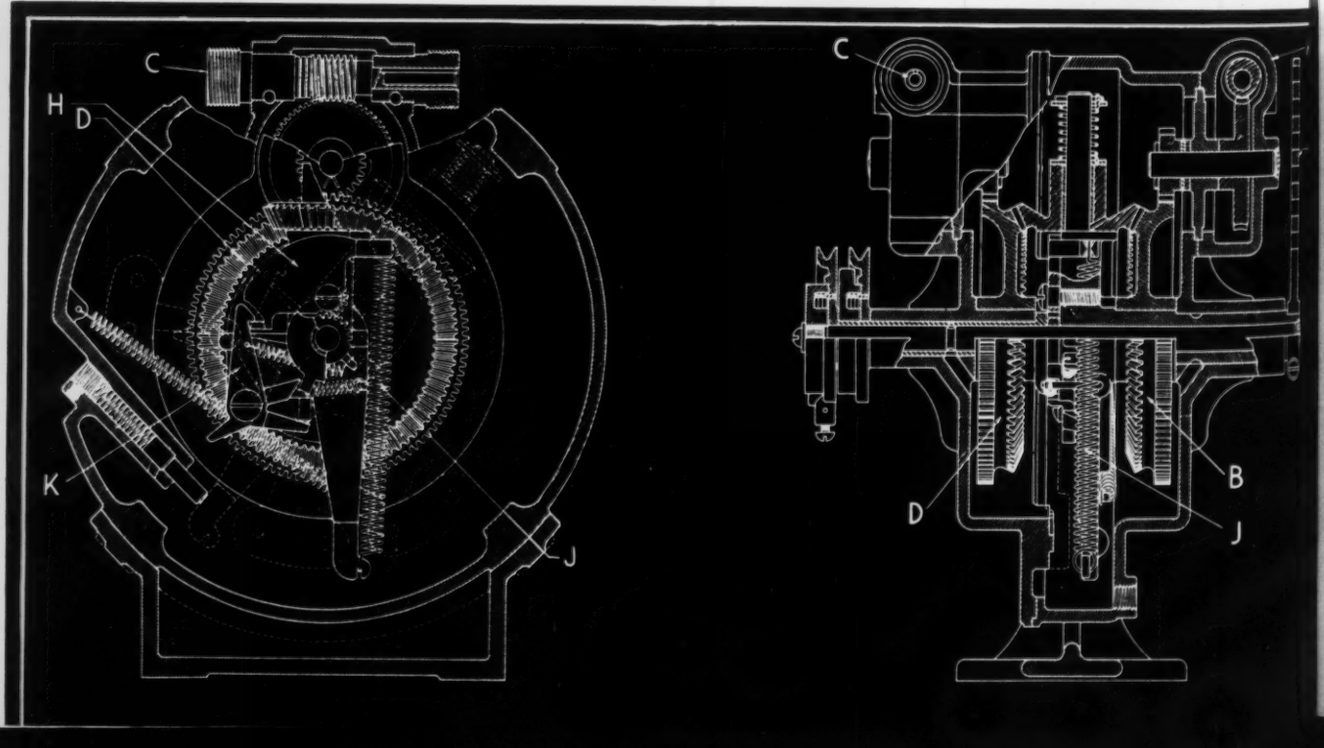
Flat springs on shell gage, above, facilitate operation as well as provide effective protection for the dial gages. Each indicator anvil is supported by four springs mounted on a fixed block. Stops on the blocks protect the instruments by preventing movement of anvils beyond the limit of the gages. These stops, together with the spring supports, allow faster gaging without damage from bumping and otherwise rough handling. Shell is accurately positioned on a V-anvil having tungsten contacts.

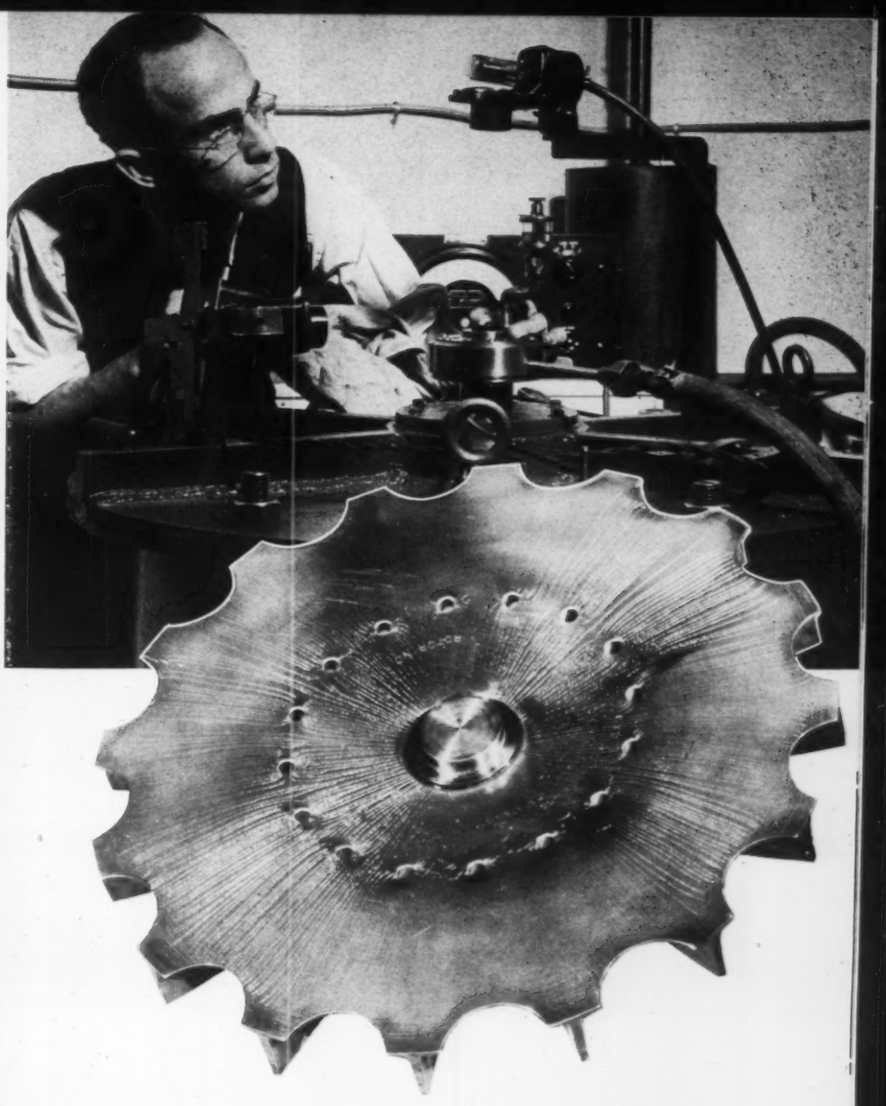


Fabric attachment utilizing retainer strip provides a quick, simple fabricating device for the cannon-carrying fighter plane, the Airacobra. Conventional fabric attachment methods entail a considerable amount of skilled handwork. Fabric is stitched to the structural members and then the stitching covered with strips of balloon tape. Besides requiring faster production, a stronger attachment was desired. The new method involves a specially developed handtool, prepared rib extrusion with a channel in the T-shape and a thin curved retainer strip, as shown in the insert at left. Fabric is positioned over the channel in the rib and the handtool rolls the retainer strip into place in the channel, the fabric being gripped tightly between the strip and the channel. Comparative tests show this method to be stronger than either the stitching or sheet metal screw method.



Differential gear governor, below, synchronizes the speed of two engines by controlling throttle position. Designed by Synchro-Master, each differential gear, B and D, is connected to its engine through a worm and gear drive at A and C, in opposite directions. When the gears are traveling at equal speeds, the position of the differential pinion does not change. If, however, speed is unequal, the pinion advances or retards, causing movement of the arm G, which adjusts the throttle of the following engine to equal that of the master engine. To guard against overtravel in event of excessive difference between speeds of the two engines, a cam and trip arrangement, H, K, J, are employed. In event of overtravel of the differential pinion, the cam arrangement lifts it from engagement with the differential gears. When a synchronous electric motor replaces the master engine, the governor provides constant speed control





Stress-coat pattern, right, formed on varnished surface shows graphically the stresses obtained in rotating at high speeds. For testing these turbosupercharger rotors, General Electric designed the vacuum chamber illustrated to develop sufficiently high speeds to make a pound mass exert a pull by centrifugal force of over 100 tons. If such speeds could be reached in open air, a large amount of energy would be required to overcome the air resistance. By working in a vacuum, a five-pound compressed air turbine is all that is needed to obtain speeds up to 60,000 revolutions per minute. Because the rupture speed of some rotors is 40,000 revolutions per minute, the vacuum chamber has massive steel walls. Speed is measured by a phototube and mirror arrangement. The mirror is mounted on the rotor shaft to reflect light upon the tube. Impulses caused by this action indicate speed on the dial of a frequency meter.

Unit design of control cabinet, below, for can filling machine developed by the American Can Co. permits the addition of auxiliary units to the machine yet provides for keeping the control unit at the operator's end. Shape and dimensions of the machine base are retained to give integral appearance. Being removed in the illustration to show method of attachment, the unit incorporates a low-voltage transformer at the rear of the panel, and at the front a circuit breaker, starter and other control devices. Cabinet cannot be lowered unless the circuit breaker is in the off position.

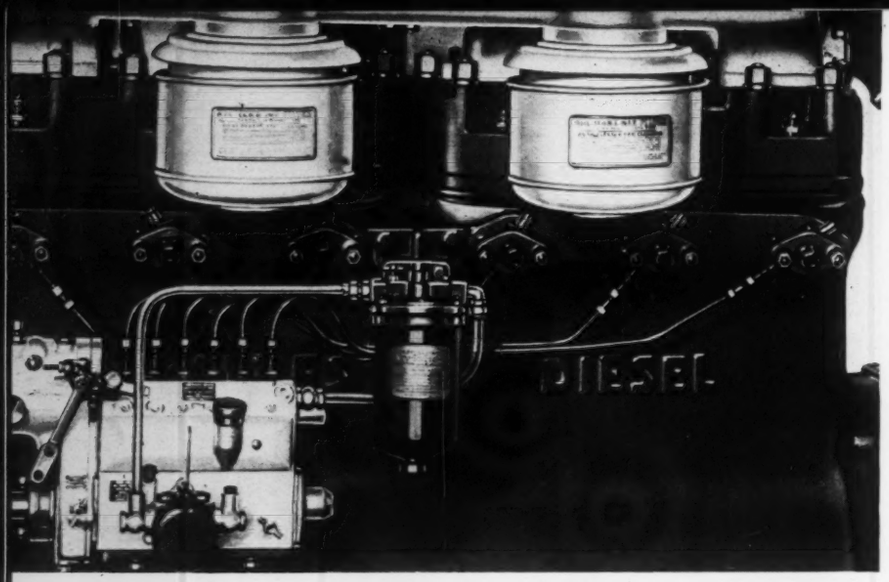


Fig. 1—Fittings for injector system are required to withstand severe vibration as well as pressures up to 6000 pounds per square inch

Primary Consi

By John W. Greve

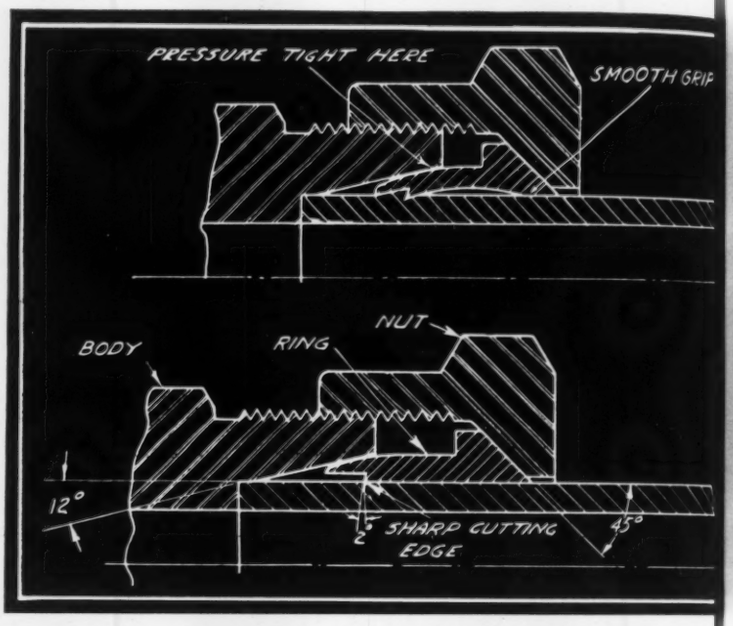


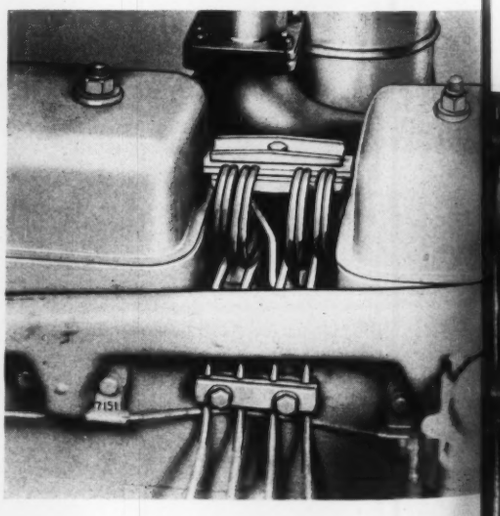
Fig. 2—Above—Principle of a compression fitting designed especially to withstand high pressures

IN SELECTING fittings for tubing or piping as installed in increasing quantity in today's war machines, pressures and the extent of vibration encountered are usually the controlling considerations. Ease of assembly and maintenance in the field are second only to the need for a dependable joint. Breakdown of a fitting, though seemingly unimportant can be just as disastrous as that of any other mechanical part.

Corrosive effects of liquids or gases can be minimized by the choice of proper materials. Thermal stresses are usually negligible or are absorbed in the tubing system. With respect to pressure problems, many fittings are designed to withstand the bursting pressure of the tubing to which they are applied. Vibration, however, is not as simple a matter and care should be exercised in both the selection of fitting and method of application to minimize vibration stresses, if present. Typical of applications requiring dependable operation under high pressure and vibration is the diesel injector system shown in *Fig.* 1.

Various styles of fittings with almost countless combinations of connections for T's, crosses, elbows, male and female threads in sizes ranging from ⅛ to 2 inches are available for compression, flared, soldered or brazed joints. Standard fittings ordinarily can be applied to any problem and should be considered in preference to special designs wherever possible. Reasons are obvious and include lower cost, better delivery, and easier maintenance of equipment in the field.

Fig. 3—Below—Pig-tail loops supported at center absorb considerable vibration that otherwise might weaken the joints



Probably the simplest and one of the oldest fittings is the familiar compression type for brass and steel tubing. The joint consists of a sleeve or ferrule, a nut and a body member. With the nut and ferrule over the tubing and the tubing inserted in the body, tightening of the nut compresses the sleeve between the tubing and fitting, giving a tight joint suitable for operation at moderate pressures.

Because commercial tolerances might involve a joint with a maximum bore in the ferrule and a minimum outside diameter of tubing, it is possible that in assembling the joint the ferrule would become eccentric to its seat. This naturally would weaken the joint and make it undesirable for heavy-duty service.

...tions in Selecting Fittings

To obviate this difficulty, a joint has been designed in which the ferrule and nut are integral, but grooved so that they shear apart during assembly. In this way the sleeve is seated concentrically in the body of the fitting before shearing takes place, causing compression to be uniform around the tube when the nut is tightened. This fitting has an additional advantage from the point of view of assembly costs. Having the action of a three-piece joint it is a two-piece assembled fitting, with the nut loose. Tubing is merely inserted and the nut tightened to provide a compression joint.

In use in Europe throughout the past eight years and domestically for three years is a high-strength compression fitting known as the Ermeto fitting. Basic principles are shown in *Fig.* 2. The ring or ferrule is machined so that it has a sharp leading edge. When the nut is tightened the ring slides forward and, because it has this sharp edge, cuts its own seat on the tube. Rings for various kinds of tubing are made of a material that is always harder than the tube itself. On copper tubing, a copper-plated steel ring is used. For steel tubing, a steel ring with a shallow cyanide case is employed.

To strengthen the joint against vibration and obviate possible failure where the edge of ferrule cuts a ring on the tubing, *Fig.* 2, the end of the ferrule has a smooth bore which is clamped tightly on the tube by the angular face of the nut after the cutting edge of the ferrule has formed its seat. Vibration on a properly fitted joint should not reach beyond the clamped portion for maximum strength.

Flange-type fittings employing this principle have been in wide use in England and France and can be satisfactorily applied to tubing as large as 12 inches in diameter. Fittings, however, are not available in this coun-

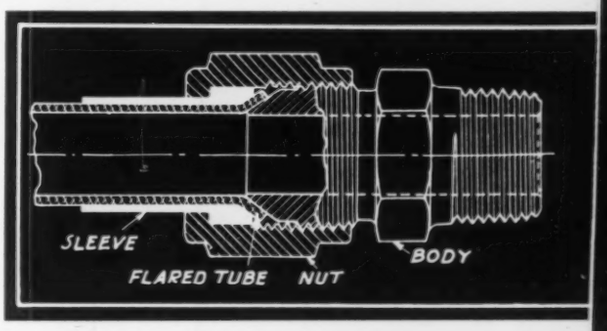


Fig. 5—Above—Flared fitting is strengthened by sleeve. This design is used in aircraft

Fig. 6—Below—Inverted flare joint in hydraulic lines on mower have proved satisfactory in service

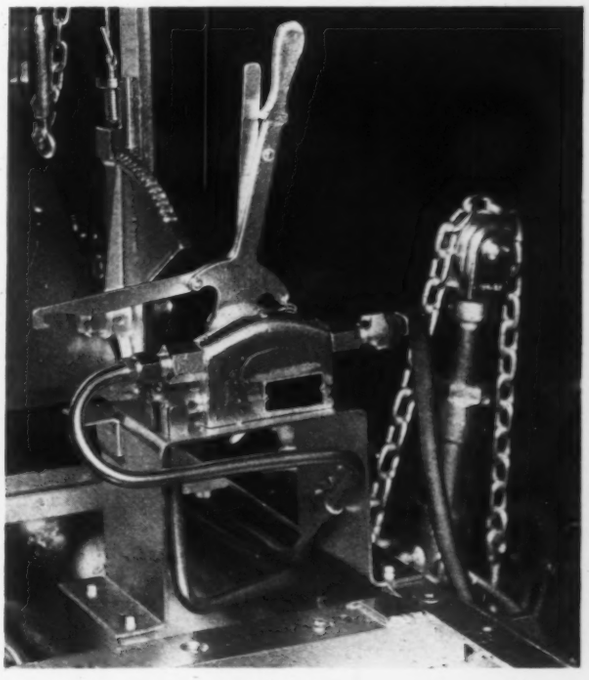
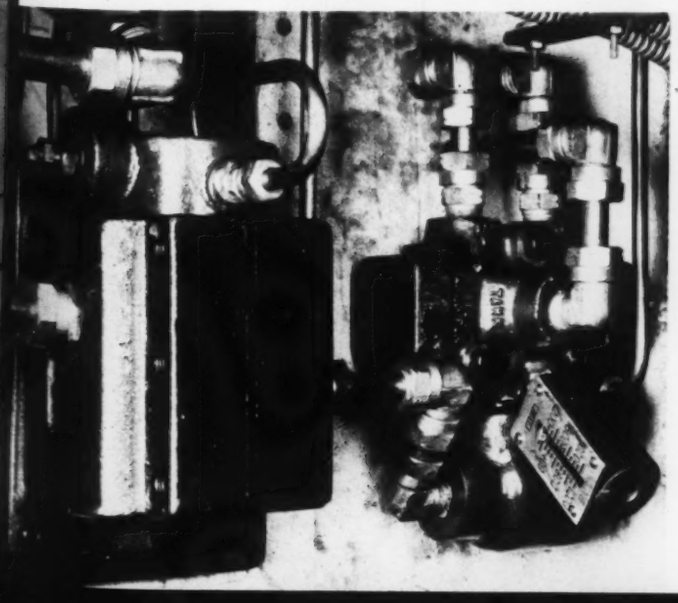


Fig. 4—High-pressure compression fittings in hydraulic system of a milling machine



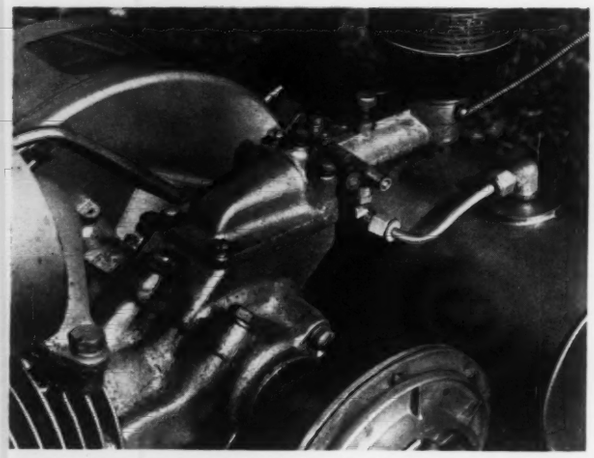


Fig. 7—Floating compression joint is used in fuel lines of power mower to absorb vibration

try in sizes larger than 1½ inches outside diameter.

Close-coupled joints employing this type of fitting are shown in *Fig.* 4. The operating valves for a contour milling machine exert hydraulic pressures on the fittings of about 1,000 pounds per square inch. Particularly suitable for high-pressure work, these fittings are designed to hold pressures through the burst strength of the tubes without any leakage or loosening. They have been applied successfully in refrigerating equipment for freon and ammonia which are hard gases to hold.

In all joints involving metal ferrules, the ferrule becomes a part of the tubing. Joint may be assembled a great number of times but, if the tube is replaced, a new ferrule is required. From point of view of resistance to vibration, any scratch or marking on the tubing to which movement could reach, might result in fatigue failure. Extended nuts have been applied to add support to the joint. Again, commercial tolerances could easily involve sufficient clearance to cause high stress concentrations in the joint and extended nuts should therefore be applied with care.

Design of tubing layout may often obviate excessive strain on the joint. For instance, no joint should have its axis in the plane of vibration, because a pull should never be exerted on the joint.

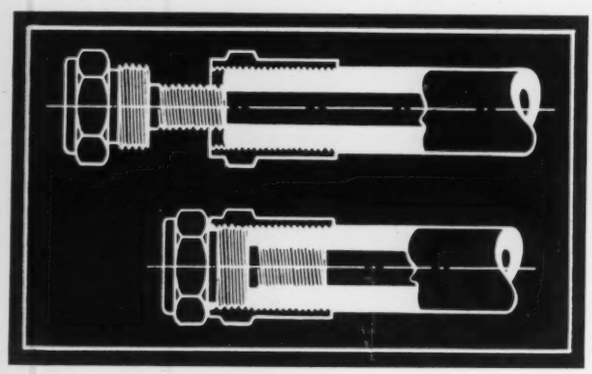


Fig. 8—Two-piece fitting for hose

Application of an elbow fitting to turn the joint at right angles to the plane of vibration, allowing the vibrations to be absorbed in a tubing bend is useful. Also, if a single bend or U-bend is not desirable, a "pig tail" loop as shown in *Fig.* 3 may prove useful in solving an otherwise troublesome application.

Flared fittings have been standardized by S.A.E. and were developed to meet a need for high-pressure work. Being a two-piece fitting, the body has a male thread and a 45 degree seat at the end of the thread. The nut has a complementary seat which holds the flared tube against the seat. Fitting may be reassembled repeatedly. Each assembly weakens the joint slightly, however, because of the wiping action thinning the section and of the possibility of incipient fatigue cracks. A variation of this design, the inverted flare fitting, makes a more compact joint and is lighter in weight. The body has a female thread with its seat at the bottom of the thread. The nut in turn has a matching thread and the tube flare seats well within the body of the fitting. This style is used for high-pressure

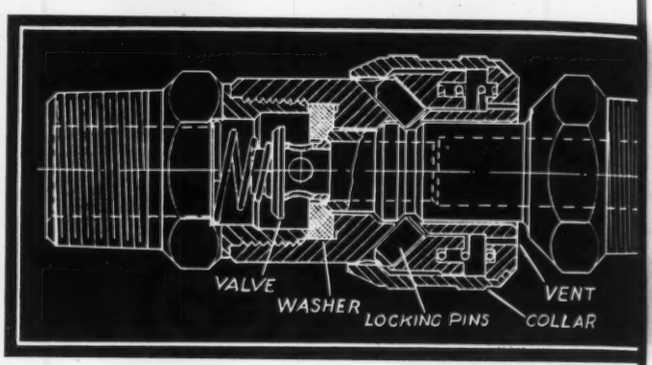


Fig. 9—Snap-type coupling increases portability of pneumatic devices

hydraulic piping and is shown applied to a sickle-mower unit in *Fig.* 6.

Developed to overcome a weakness of the S.A.E. fitting, a design more resistant to fatigue and less affected by reassembly is the sleeve-type flared fitting in *Fig.* 5. A metal collar with a 45-degree matching face holds the flared tubing against the body seat by the tightening action of the nut on a square shoulder. In this way the tube itself receives no wiping action from the nut and the possibility of the tube becoming weakened by scoring or excessive working is therefore eliminated. This type of fitting is now being used widely for aircraft applications where the bodies of the fittings are either anodized aluminum alloy or nickel steel.

Where amplitude of vibration goes beyond the endurance of conventional fittings but where pressures are low, a floating joint utilizing a sleeve of resilient material such as neoprene has been found satisfactory. Tube end is flared and the nut compresses the sleeve when drawn tight on the body of the fitting, thus allowing a limited free oscillating

(*Continued on Page* 142)

Carbon Offers Solution to Materials Problems

By Fred W. Korfmann

Morganite Brush Co.

ACUTE shortage of engineering materials has given rise to the current unprecedented search for alternatives. It is a well-known fact that in many cases the application of an alternative material has led to improvement in the redesigned part. When a replacement material of this nature is found, of which there is no shortage, it seems too good to be true. Such a material, however, is carbon and such improvements are often attained by use of carbon machine parts.

Carbon is a familiar material in electrical applications. Perhaps for this reason it is sometimes overlooked as a structural engineering material. Already, however, it has had extensive mechanical application and therefore deserves consideration not only as an alternative material but as a permanent addition to the designer's materials specification list.

Carbon and its generic form

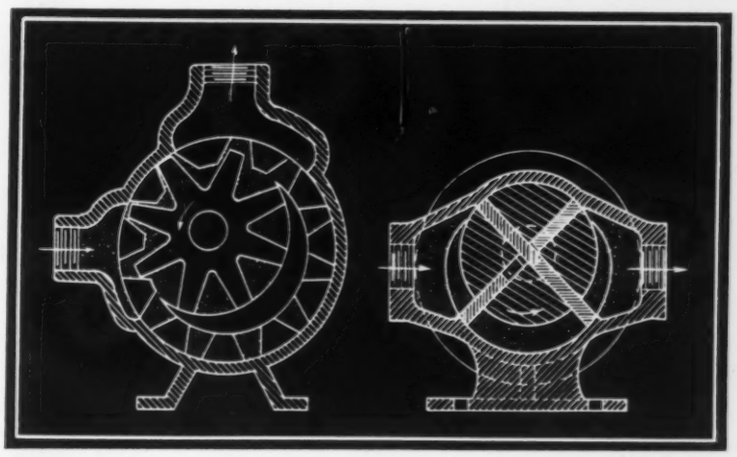


Fig. 1—Below—Molded carbon rotors give outstanding life in corrosive service as well as under conditions of poor lubrication

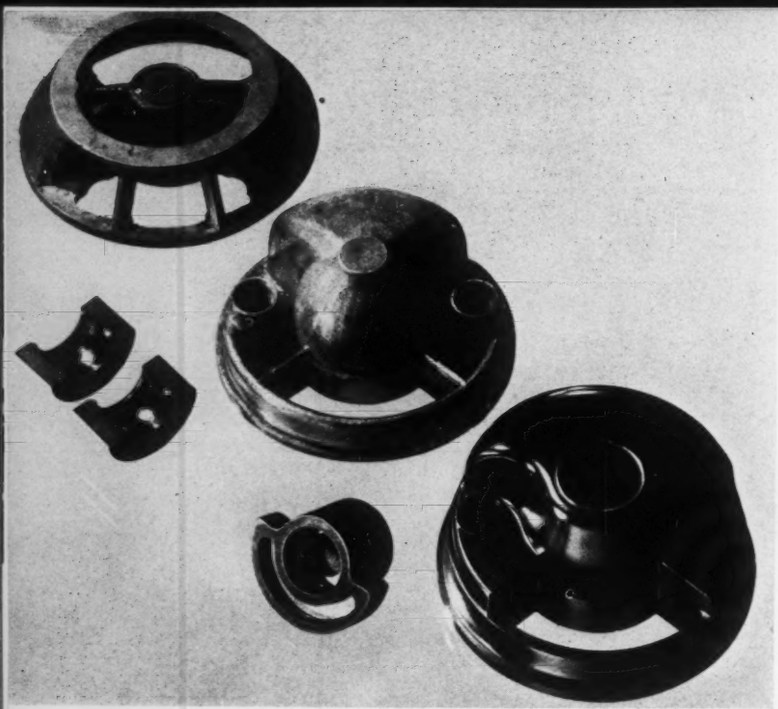


Fig. 2—Evolution of gasoline pump metering valve from cast iron to aluminum to carbon results in the elimination of sticking

graphite are obtainable in a wide range of physical properties. As in the case of any engineering material certain design considerations peculiar to itself must be observed in the handling and specification of carbon parts. In order to illustrate its possibilities a series of applications and case histories will be cited followed by specific design and physical property data.

Electrical applications are principally carbon brushes and contacts. Electrochemical applications are comprehensively covered in "Industrial Carbon" by Dr. C. L. Mantel. Only a comparatively small portion of this book, however, is devoted to mechanical applications, under the heading "Carbon Specialties". It is in this phase of the subject that the machine designer is most interested and to which the following discussion is devoted. Application study has been divided for the sake of convenience into three classes: (1) structural, (2) frictional, and (3) electrical. It is hoped that these discussions, covering typical carbon uses, may serve to indicate solutions to many present-day engineering problems.

Pump gears and blades formerly made of bronze and various laminated plastics have been replaced successfully by carbon. Because of its chemical inertness it was first given consideration for applications in chemical processing equipment. As a result of its lower friction losses and lower rate of wear when operating against metal parts it rapidly became apparent that an extension of its use to non-corrosive conditions was amply justified. Such additional qualities as freedom from swelling or warping contribute to this conclusion. In addition, in blade type rotary pumps, carbon's low specific gravity and its ability to operate for long periods without lubrication are important factors. Operation of such pumps at much higher speeds are possible for these two reasons. Two such applications are shown in the drawing *Fig.* 1.

The pump shown at the left of *Fig.* 1 operates at 1200 revolutions per minute handling, at low pressures, a water solution of 9 per cent sulphuric acid, 16 per cent sodium sulphate, and 1 per cent zinc sulphate at a temperature of 40 degrees Cent.

The vane type pump shown at the right of *Fig.* 1, also operating at 1200 revolutions per minute, handles oil and other liquids at pressures up to 1000 pounds per square inch. As an example of higher attainable speeds, 2-inch diameter carbon rotors have been used in air pumps operating at 3300 revolutions per minute. In pump applications such as these two, the maintaining of minimum clearance between the rotors or vanes and the housing is of vital importance. Because of its low coefficient of thermal expansion (.000001 per degree Fahr.) the use of carbon for these parts leads to unusually high operating efficiencies.

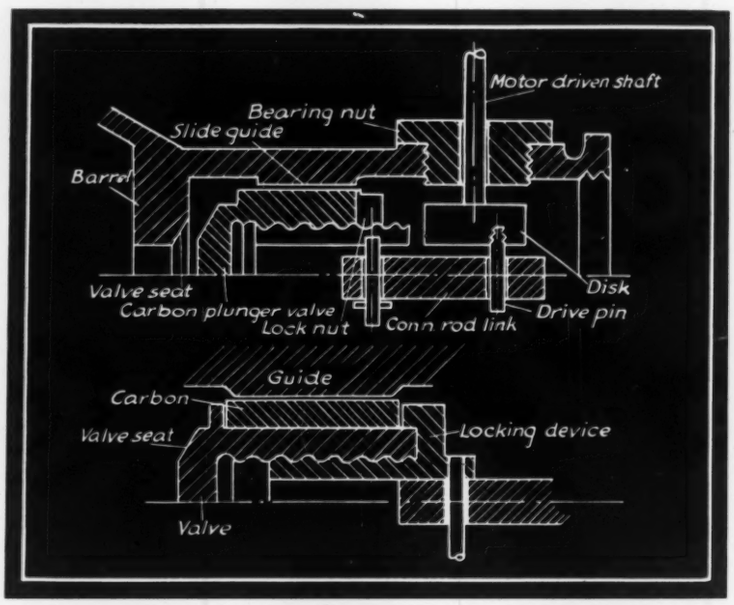


Fig. 3—Direct substitution and a redesign for optimum use of carbon result in the solution of operating difficulties with cylindrical valve

In gasoline metering pumps serious trouble was experienced as a result of gumming and sticking of the valves as well as the scoring of the zinc base die-cast housing upon which the cast-iron metering valve operated. In an effort to overcome these difficulties die-cast aluminum was tried with some success. A specially compounded and designed carbon valve was substituted with improved results. In *Fig.* 2 are shown the two original metal valves on the left and the finally developed carbon valve on the right. This valve is an excellent example

of the possibilities for molding special shapes and will be discussed in greater detail in the section devoted to design data.

Another interesting and similar application of the slide valve for gas meters is shown in *Fig.* 6. Formerly a white metal slide valve was used, operating against a similar white metal seat. High and irregular friction and sticking of the valve due to gummy formation on the valve seat as well as noisy operation were experienced. After a series of tests a grade and density of carbon was developed which would both seal the gas across the valve and keep the grate clean. Quiet operation, low even friction, and a low rate of wear are obtained. This application also exemplifies the manner in which metal inserts may be applied to carbon parts.

TABLE I

Typical Physical Properties

Property	Molded Carbon	Aluminum Die Casting	Phenolic Plastic
Compressive strength (psi.)	2,000 to 25,000	9,000 to 46,000	16,000 to 36,000
Tensile strength (psi.)	400 to 3,500	16,000 to 32,000	4,000 to 11,000
Shear strength (psi.)	3,200 max.	18,000 to 32,000	10,000 to 15,000
Impact strength (ft.-lb. Izod)	.10-1.2	‡	.10-2.7
Specific gravity	1.4 to 2.2	2.6	1.27 to 2.09
Temperature Limits (deg. F.)	850†	.....	240 to 300
Chemical resistance	Unaffected	Limited	Limited
Thermal expansion (per deg. F.)	.000001 to .000006	.000010 to .000015	.00002 to .000075
Hardness	40 to 135 (scler.)	75 to 110 (brinell)	30 to 45 (brinell)
Elastic modulus (psi.)	1.33×10^6 to 2.42×10^6	10×10^6	0.5×10^6 to 4×10^6

†Graphite grades suitable for higher temperatures.
‡Grades are obtainable with lower and higher values than plastics.

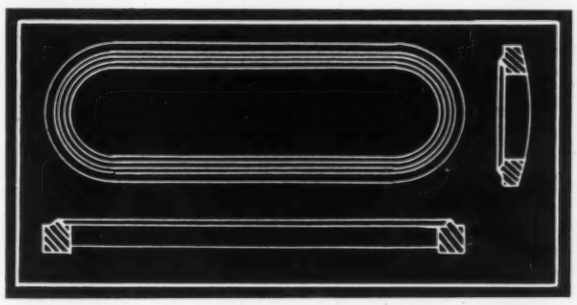
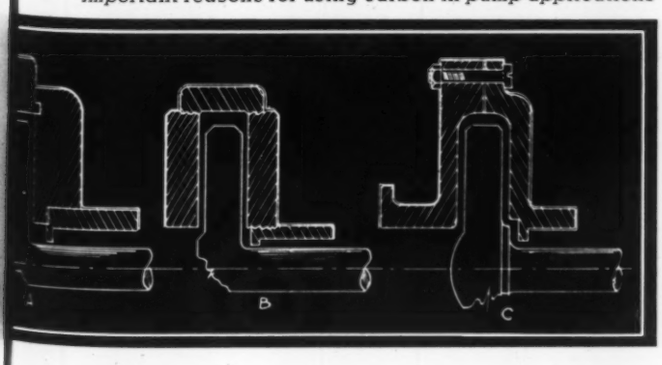


Fig. 4—Distributing parts of a rotary air governor are sealed against ten pounds per square inch pressure

Fig. 5—Corrosion resistance and low expansion rate are important reasons for using carbon in pump applications



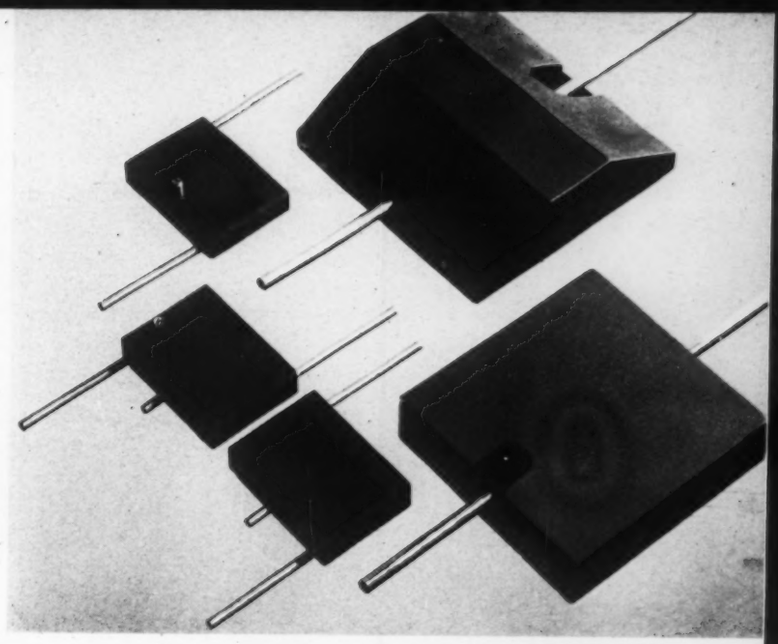


Fig. 6—Quiet operation, even friction and low rate of wear results from use of carbon gas meter valves

Another interesting valve, *Fig.* 4, seals ten pounds pressure across distributing parts in a rotary air governor application. The carbons, as shown, rub against the inside diameter of a magnesium cylinder at approximately two revolutions per minute; the entire life of the assembly has been estimated at 45,000 revolutions.

Clutch plates and rings formerly made of cork and metal have been successfully replaced with carbon parts. The coefficient of friction in one application has remained constant at .22 to .35 over a period of years. The friction surface can be either on the inside diameter, outside diameter, or face. Freedom from squeaking is obtained.

TABLE II

Typical Frictional Values

Combination	Unlubricated or Poorly Lubricated	Well Lubricated
Metal on metal	.35 to .70	.007
Carbon on hard steel	.18 to .30	.04 to .08
Carbon on glass	.17	.....
Rubber on steel	...	.05

Metal can be compounded with carbon to lower or increase friction.

Illustrated in *Fig.* 3 are two redesigned variations of an electrically operated plunger type steam valve in which trouble had been experienced, when a cast-iron plunger was used, by seizing of the plunger on its three supporting guides. The upper drawing illustrates how carbon was used for the plunger without any other redesign of the valve. In the lower drawing of *Fig.* 3 is shown a redesign that permits the use of a simple hollow carbon cylinder, resulting in appreciable economy. In this steam valve which is also used for water and fuel oil, the steam pressure at the thinnest section of the carbon is 160 pounds per square inch. In this and also

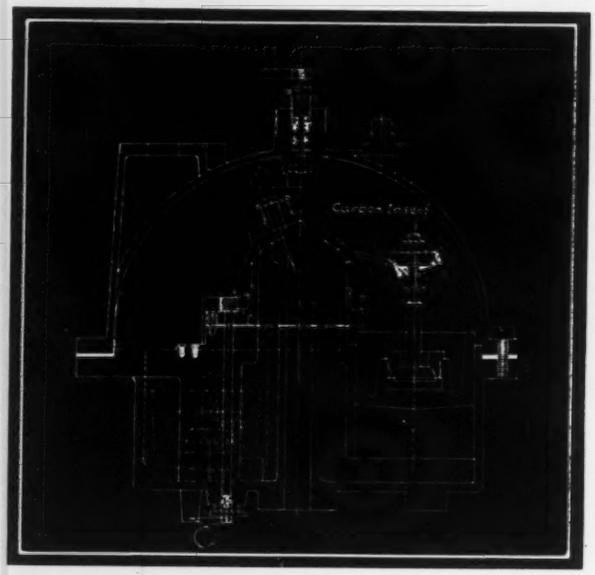


Fig. 7—High temperature service and necessary self-lubricating properties require use of carbon for many bearing purposes

manually operated valves special high density and high impact resistance grades of carbon are employed. Many such manually controlled valves are operated by driving forks or similar mechanisms which fit into molded grooves or blind holes in the carbon. To reduce local wear, metal fittings for hole reinforcement and similar strengthening purposes are molded into, or shrunk on, the part.

Structural strength and piece size in the required density are the limiting design factors and it will be seen from the illustration, *Fig.* 5, how these factors are handled. In such designs, consideration is given to metal plating or spraying of the finished assembly to increase shock resistance. Ceramic glazes can also be applied to such assemblies for improved appearance, reinforcement, and protection. Rubber can be readily vulcanized to carbon, which material acts as a casing, shock absorber, or cushion for applications in severe service.

Low Inertia Important in Wabble Plates

In meters of the wabble plate type, *Fig.* 9, for liquids and semi-solids, chemical stability, low coefficient of expansion and low rate of wear are important considerations, as is also the desirability of maintaining at a minimum the inertia of all moving parts. In such applications the use of carbon for the wabble plate achieves these ends in addition to permitting manufacture to extremely close tolerances. Molding and other manufacturing processes to attain efficiency and minimum cost are problems for the carbon manufacturer.

Carbon bearings and bushings are used principally where high temperatures demand self-lubricating properties or where gases or liquids would prevent satisfactory fluid lubrication. One such part is the axial cylinder pump illustrated in *Fig.* 7. In this case hemispherical carbon parts fastened to the end of the piston rod bear on metal inserts in the piston, actuating the wabble plates. Another interesting bearing job is on a 1000-gallon sump pump. Here a carbon steady bearing is employed eight feet from the motor drive. It replaced a bronze bearing which was pounded out of shape in about six months. The carbon bearing differed from the metal in that it would not flow and become elliptical as had the metal. The carbon has been run over several years and at last inspection had worn less than .001-inch; no measurable shaft wear. Some applications in paper mills require the carbon bearing to support over 1000 pounds per square inch at low speed. Thrust bearings or seal noses of carbon composition have been covered in some detail in a previous MACHINE DESIGN article*. An outstanding application of a metallic carbon composition seal is that in automotive, industrial, and other fluid drives. Here the seal floats between two metal surfaces at high speeds and temperatures in a manner described in detail in many recent publications.

Important developments are a new cartridge type oil seal which solves the problem of obtaining a carbon seal requiring small space. In seal service, speeds as high as 60,000 revolutions per minute at 30 pounds per square inch pressure have been satisfactorily handled. There are many successful oil seal applications on aircraft.

Fastening Problems Solved

Problems of attaching or fastening carbon parts to adjacent parts in an assembly have in the past caused considerable difficulty. As a result of the development of new methods carbon may now be satisfactorily attached to metallic bellows or other metal parts, may be vulcanized to rubber, may be metal sprayed or plated and may be coated with porcelain enamel or other ceramic materials.

Use of carbon and metallic carbon compositions in piston rings of pumps and compressors is so well known as to require little mention here. An outstanding advantage of this application is that in addition to its self-lubricating qualities the carbon imparts a corrosion-resistant film on the cylinder wall in the same manner as on the surface of shafts running in carbon bearings.

In several instances it has been found preferable to use cylinder liners of carbon in conjunction with cast-iron or other metal piston rings. One application on a weighing scale indicates when such a scheme is desirable. As originally designed the scale utilized a carbon plunger operating in a metal cylinder. Satisfactory performance was obtained in the normal range in which the scale was used. However, outside of this range sticking of the plunger often occurred. This was found to be due to the fact that the carbon plunger polished the section of metal liner corresponding to the normal working

* "New Designs Broaden Scope of Shaft Seals," MACHINE DESIGN, November, 1940.

range. Outside of this range the liner developed oxide films which altered the wall diameter and changed the friction drag. The solution to this difficulty was in making the cylinder lining of carbon and the plunger of metal. Thus regardless of the working range of the scale the metal plunger attained a continually polished surface.

For extremely large sized applications, problems of required density and necessary mechanical reinforcements are still major obstacles; however, on applications of moderate size successful use of frictional equipment has been obtained even under high-speed operating conditions.

Produces Glaze on Bearing Metal

The property of being able to produce a glaze or highly polished surface on the co-operating metal parts with consequent low wear rate has resulted in the development of special carbon grades for the trolley shoe inserts of street railway systems. Incidental to the advantages of greatly reduced wear and increased life of the overhead wires is the fact that static radio interference is also thereby eliminated. Outstanding requirements for the application are fairly hard compositions, low water absorption, self-lubrication, and good electrical conductivity. All of these specifications are met satisfactorily by the assembly shown in *Fig.* 8. A metal shroud or housing is designed to accommodate the carbon shoe which alone bears on the wire. The metal housing adds to the mechanical strength of the assembly and permits simple replacement of the carbon shoe. When bronze or hard steel shoes were used the average life of overhead wire on street railway systems was only from about 20 to 30 years. Experience with the carbon insert indicates that this life will be increased to over 100 years. Current-carrying capacity of similar assemblies in mine service is up to 200 amperes. Contact pressure between the collector and the wire is maintained at a minimum of 10 pounds.

An analogous development is the application of carbon strips to electric locomotive pantographs. Life of these strips is in the neighborhood of 50,000 miles. The problem in this case was the development of a sufficiently strong carbon compound but one which still possessed the desirable frictional and electrical properties. This has been accomplished

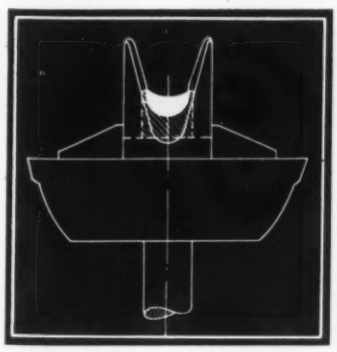


Fig. 8 — Carbon shoe inserts greatly increase life of overhead wires in street railway systems

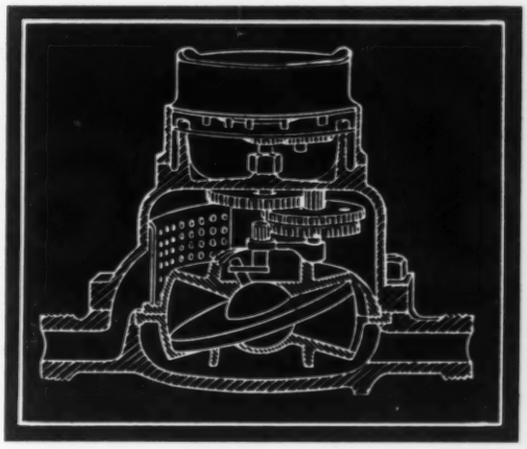


Fig. 9—Possible close manufacturing tolerances contribute to the use of carbon for wabble plates

ultimately by making this strip a composite of three or four strips extending the full length of the pantograph pan. Problems of fastening and methods of reducing shock to a minimum without sacrificing full support for shear strength have been solved.

Physical properties of carbon are tabulated in TABLE I, and contrasted for the sake of comparison with aluminum die castings and phenolic plastic. The wide range of compressive and tensile strengths provides a key to the large number of available compositions and compounds which may be specified by the designer. Logical inference to be drawn from the existence of such a large number of grades is that it is the carbon manufacturers' business and responsibility to supply that grade which possesses the physical properties necessary for the specific application. The engineer and designer should, therefore, consult with the manufacturer in the early stages of his design for applying carbon parts. A brief discussion of the process of making carbon parts will provide a broad picture of the reasons why size, shape, and contour affect homogeneity and physical properties of the final part.

Basic Ingredients and Process

Basic materials are natural graphite, artificial graphite, petroleum coke, lampblack and retort carbon; with pitches, tars and other binders. The proportion of each is controlled for specified results and metals in powdered form may be added for special qualities. In this connection data on brush grade compositions are contained in "Carbon Brushes and Electrical Machines," by P. H. Brown, "Carbon Brushes" (Newkerchen-Shobert), and "Industrial Carbon." The powders are thoroughly mixed with binders and then pressed to the required form. Following this the molded (green) blanks are kilned at high temperatures, such that the binder is carbonized. This operation requires as many as ten days depending upon the grade. After cooling and inspection, any necessary machine oper-

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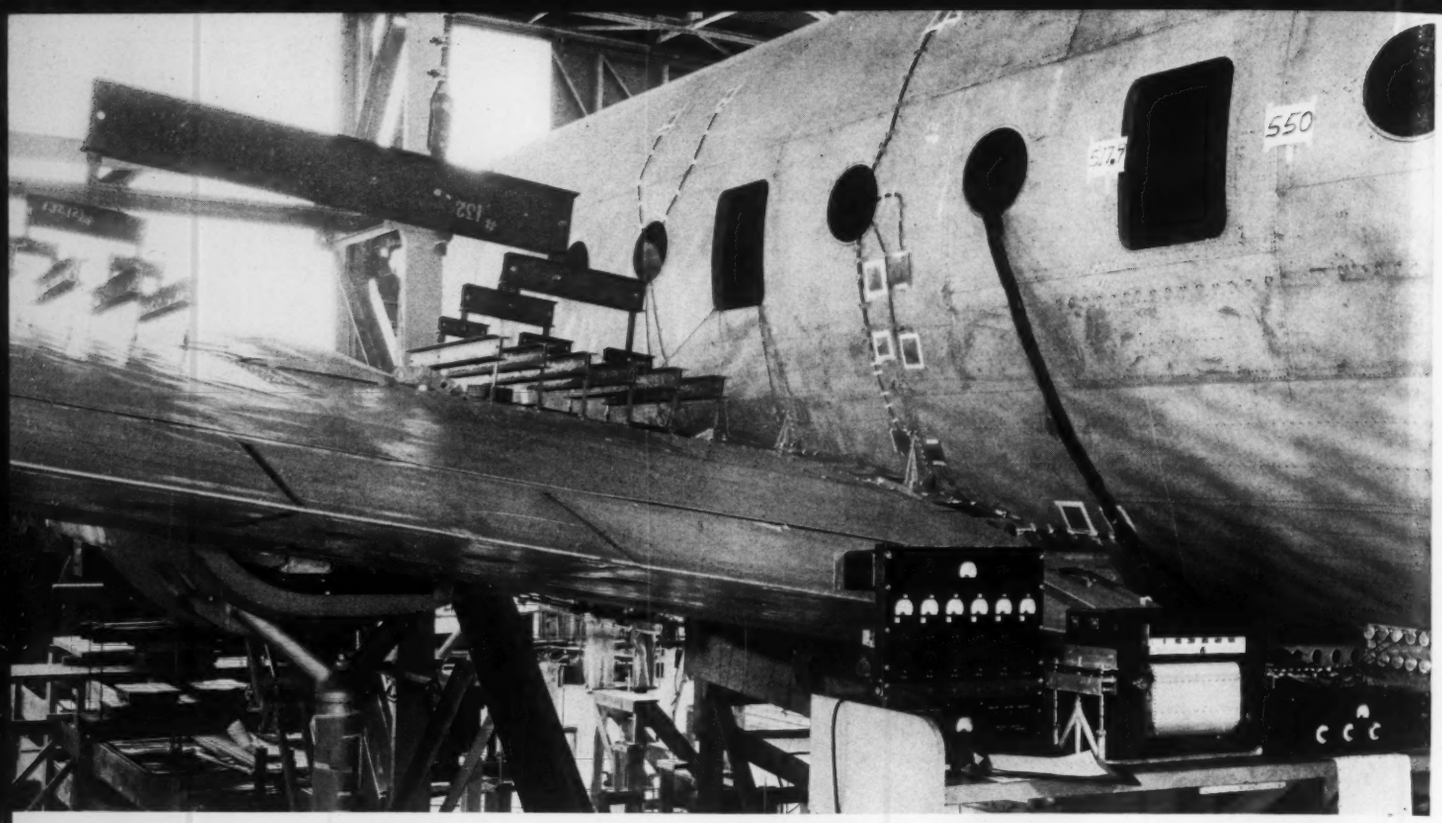

Fig. 1—Application of strain gage technique of analysis results in precise stress data for such complex indeterminate structures as airplanes

Strain Gages—Key to Indeterm

INCREASING complexity of mechanisms and structures confronts the engineer with more and more difficult problems in stress determination. Many of these problems, in such structures as airplanes, for example, defy solution by usual empirical and analytical means. Application of the strain gage technique may afford, as a "last resort" measure, a key to the solution of these problems.

Strain gage technique might at first glance seem so highly technical a subject as to occasion some surprise at interest in it at a time when production problems seem to require all of our attention. Actually, of course, the greatest possible aid to increased production is to start with the original design and simplify the structure itself, resulting naturally in a simplification of the entire production problem. Better understanding of the problems involved has already allowed considerable progress in the matter of reducing the complexity of aircraft.

Stressed-skin airplane wings, because of their nonuniformity of cross section; lack of homogeneity due to spars, struts, etc.; existence of "wave" stresses, vibrations and unsymmetrical load distribution do not lend themselves to analysis by conventional bending theories or even by mechanical strain gages. Electrical resistance strain gages, however, judiciously located at several points on the wing surface can be made to yield accurate, instantane-

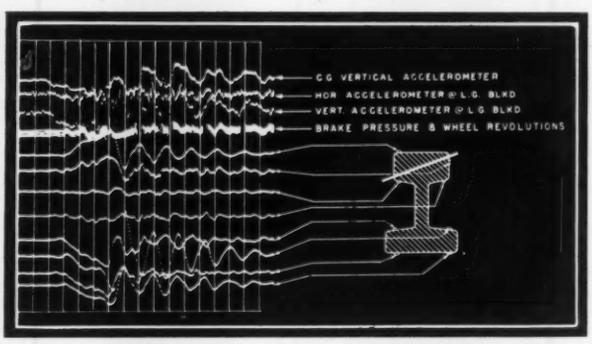

Fig. 2—Investigation of an unsymmetrical I-beam section yields the oscillograph traces shown at the left

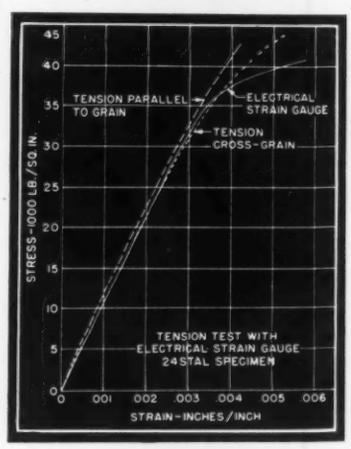

Fig. 3—Close correspondence of strain gage stress data with those obtained more conventionally is limited, in dural, to stresses up to 37,000 pounds per square inch

ous values of the varying stresses at each point.

Discussion herein is limited exclusively to electrical resistance strain gages. Fundamentally, these gages consist of one or a properly oriented group of two or three fine wires cemented to the stressed surface under investigation. These are connected to a suitable bridge circuit and for purposes of recording or facilitating data-taking, to an amplifying circuit and an oscillograph. For static stresses a stylus recorder or even a visual meter suffices.

The two ends of each of these fine gage wires vary in spatial relationship with strains in the surface to which they are cemented. The cross section, and hence the resistance of the gage wires, varies with elongations or contractions of the gage. These variations disturb the balance of the bridge circuit, thereby affording a measure of the strain. These data, interpolated in terms of stress, may be used to exercise a profound influence on the design of the structure. The resistance units themselves have been thoroughly described by deForest and Leaderman in N.A.C.A. *Technical Note,* No. 744.

In all work with these gages it is important to realize that a strain and not a stress is being measured. Poisson's ratio corrections, therefore, must be

te Stresses

made wherever stresses not parallel to the axis of the gage exist. Where simple axial loads with a uniform stress distribution across a cross section can be presumed to exist, a single gage is adequate to determine the stress. Such a condition in complex structures is unusual, and for that reason, a more satisfactory procedure is to use a number of gages so interconnected that an average of the stresses imposed on all of the gages is read.

Assuming purely axial stresses parallel to the gage axes, the stress will be, of course, the product of the strain and elastic modulus. Indicative of the conformation of strain gage data with those ob-

BASED on a paper prepared by C. R. Strang, Douglas Aircraft Co., for the Society of Automotive Engineers, this article provides an introduction to the broad field of electrical resistance strain gage applications to complex and indeterminate structures. In flight and ground tests on airplanes, data have been obtained which are having the effect of reducing the design of such structures to an exact science

tained by more customary methods, *Fig.* 3 demonstrates that for stresses up to 37,000 pounds per square inch in dural agreement is close. At stresses above this figure a much larger increase in strain is experienced than would be expected. Useful range of the gages is, therefore, taken to be of the order of .0037 inches per inch, strain. Thus, while the stress limit for dural is 37,000 pounds per square inch, that for steel is 107,000 pounds per square inch, resulting from the product of 29,000,000 (*E* for steel) and the strain ratio .0037.

For investigations on more highly heat-treated steels it is sometimes possible to widen the apparent useful range of the gages by installing them on a

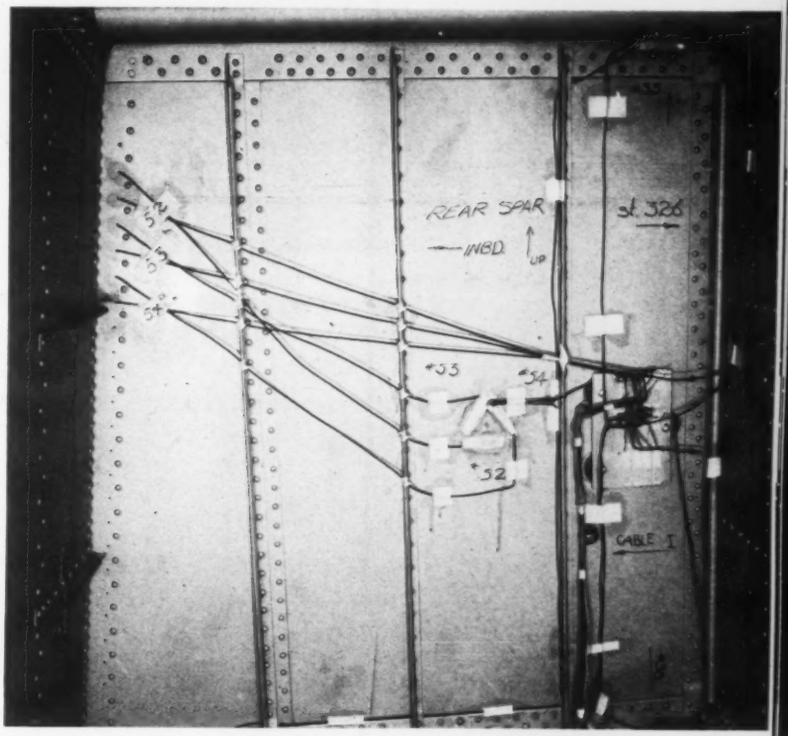

Fig. 4—Gages are conventionally installed in "delta." Dummy gages for temperature and resistance correction are shown at the right

part which is preloaded. For example, in a typical investigation of a landing gear axle for a large plane, for which the ultimate design load factor might be four, the axle may be steel, heat treated to 180,000 pounds per square inch and worked, at the ultimate load factor, to an allowable modulus of rupture of 250,000 pounds per square inch. In that case the plane, parked, fully loaded, on the ground would be experiencing axle stresses of 250,000/4 or 62,500 pounds per square inch. A gage installed while the axle was so stressed would not be overstressed when the load is removed in flight. If a landing were made at full expected applied load factor or $4/1.5 = 2.667$, the increment of stress imposed on the gage would be $(2.667\text{-}1)/4 \times 250{,}000 = 104{,}000$ pounds per square inch. This is

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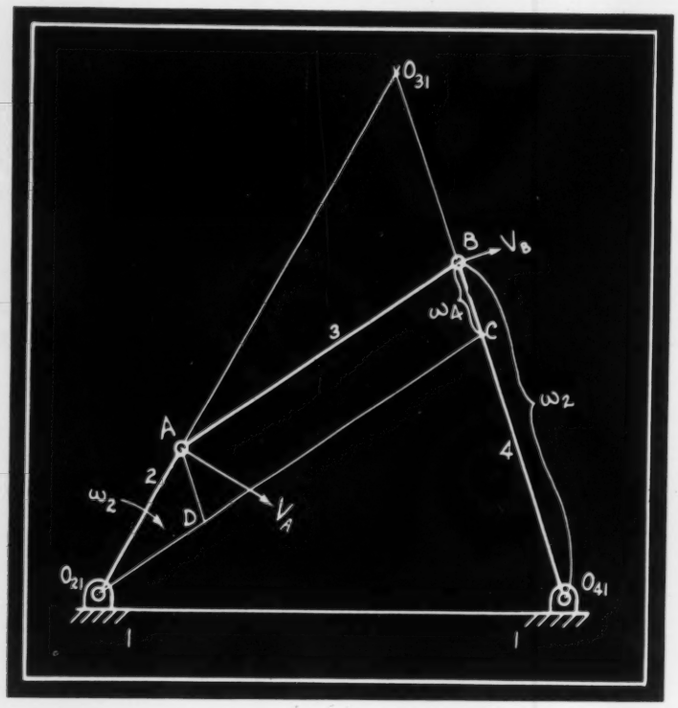


Fig. 1—Line, through the frame pin of a crank of known motion, parallel to the connecting link of the linkage defines a section of the other crank which is to the length of that crank as the angular velocity ratio

Simplifying Graphical Solution of Linkages

By H. A. Bolz

Ass't. Prof. Mechanical Engineering
Purdue University

UNNECESSARILY complex methods heretofore required for the graphical kinematic analysis of four-bar linkages have led most designers to prefer the mathematical approach to problems of this type*. While it cannot be denied that graphical solutions are inherently limited in accuracy by the qualities of the draftsmanship employed in executing them, a method as simple as the one presented herein should yield results to a degree of accuracy consistent with that obtained in the other steps involved in the design and manufacture of the machine. Furthermore, it is a time-saving method.

Considering, for example, the four-bar linkage shown in *Fig.* 1, if the angular velocity ω_2, of crank "2", is represented by the

* "Mathematical Solution of 4-Bar Linkages,"—Guy J. Talbourdet, MACHINE DESIGN, May, 1941.

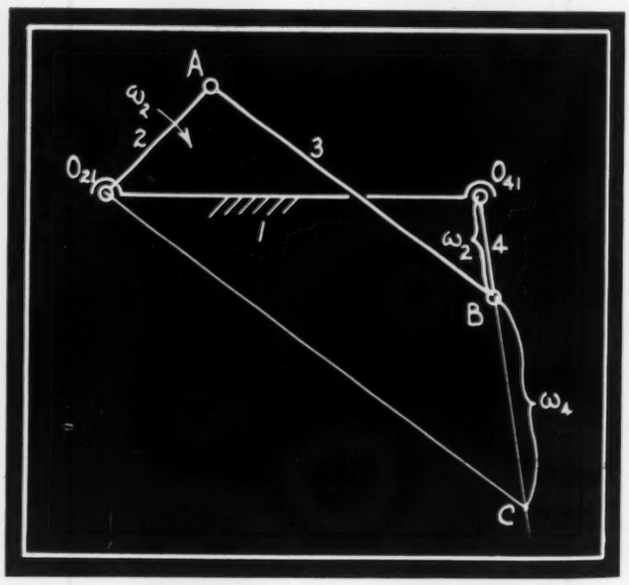


Fig. 2—In the case of a crossed-bar linkage, the analysis is similar to that of Fig. 1. The instantaneous center of rotation of the connecting link does not enter into the determination of angular velocity

length $O_{41}B$ (the radius of crank "4"), the angular velocity, ω_4, of crank "4" for this position is represented to the same scale by the length BC. The length BC is obtained simply by drawing a line through O_{21} parallel to the connecting link "3" so as to intersect link "4" at the point C.

This method may be proved as follows: The instantaneous center of rotation of link "3" with respect to the fixed frame 1-1 is located as shown at O_{31}.

Then

$$\frac{V_A}{V_B} \quad \frac{AO_{31}}{BO_{31}}$$

Also

$$V_A = \omega_2 \times O_{21}A$$
$$V_B = \omega_4 \times O_{41}B$$

Hence

$$\frac{V_A}{V_B} = \frac{\omega_2 \times O_{21}A}{\omega_4 \times O_{41}B} = \frac{AO_{31}}{BO_{31}}$$

But

$$\frac{AO_{31}}{BO_{31}} = \frac{O_{21}A}{BC}$$

Therefore

$$\frac{\omega_2}{\omega_4} = \frac{O_{41}B}{BC}$$

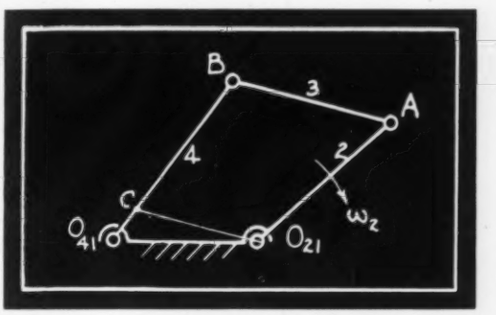


Fig. 3—This one-line construction for finding angular velocities is equally applicable to drag-link mechanisms

Other forms of this mechanism, too, respond to this analysis as shown by the examples of the crossed-bar linkage in *Fig.* 2 and the drag link in *Fig.* 3. It is useful to note that relative directions of angular velocities, as well as magnitudes, are determined by this one-line construction. In *Fig.* 1 where, obviously, both cranks turn in the same sense, point C falls inside the crankpin circle for crank "4". On the other hand, when the cranks

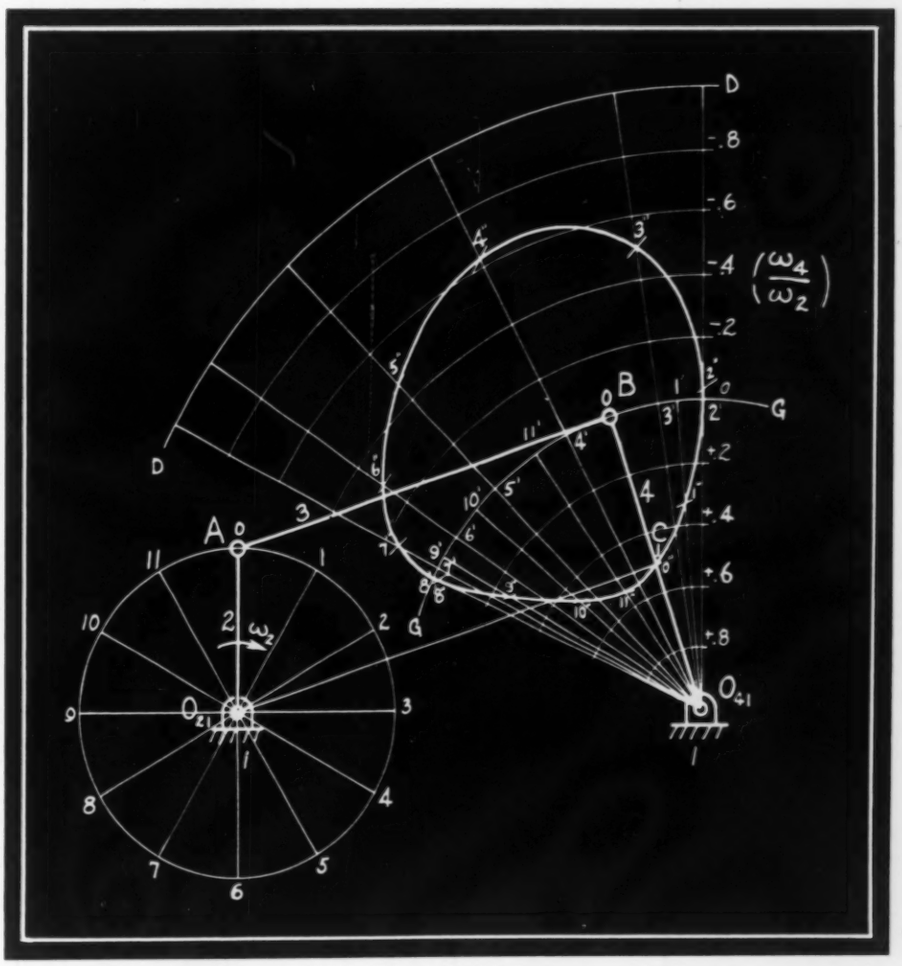


Fig. 4—Angular velocity analysis for a complete linkage lends itself to a representation of angular acceleration by graphical differentiation

turn in opposite directions, as in *Fig.* 2, the point C falls outside the crankpin circle.

In *Fig.* 4 an angular velocity analysis for the complete motion cycle of a typical four-bar mechanism is illustrated as performed by means of the one-line construction described above. As the crank "2" was moved by 30-degree increments the point C was located for each corresponding position of the crank "4". The locus of C then is the curve connecting the points O'', $1''$, $2''$, etc. This curve, referred to the crankpin arc G-G as a base line, gives the value of ω_4 for any phase of the mechanism to the same scale as BO_{41} represents ω_2. Since ω_2 is always represented by the same length BO_{41}, this curve also indicates the angular velocity ratio ω_4/ω_2, with positive values inside G-G and negative values above or outside G-G.

Acceleration by Graphical Differentiation

In cases involving one crank rotating at constant angular velocity the corresponding angular velocity curve of the other crank, constructed as in *Fig.* 4, may be transferred to a time base for further study. Such a curve would show ω_4 plotted against time and could be differentiated graphically to obtain a reasonably accurate curve of the angular acceleration of crank "4" for a subsequent inertia study.

Referring again to *Fig.* 1, it will be seen that an analysis of the angular velocity of link "3", too, may be carried out by a method similar to that above. Pass through point A a line parallel to crank "4" to intersect $O_{21}C$ at point D. The length $O_{21}D$, then, will represent the angular velocity of link "3", ω_3, to the same scale as length AB represents ω_2. The proof of this property is similar to that given at the beginning of this discussion.

$$\frac{V_A}{V_B}=\frac{AO_{31}}{BO_{31}}$$

$$V_A=\omega_2\times O_{21}A$$

$$V_B=\omega_3\times BO_{31}$$

$$\frac{V_A}{V_B}=\frac{\omega_2\times O_{21}A}{\omega_3\times BO_{31}}=\frac{AO_{31}}{BO_{31}}$$

$$\frac{\omega_3}{\omega_2}=\frac{O_{21}A}{AO_{31}}=\frac{O_{21}D}{AB}$$

While this construction does not furnish as convenient a means of representing the angular velocity ratio, ω_3/ω_2, as does the previous method for determining ω_4/ω_2, one is seldom interested in the ratio between the angular velocity of the connecting link and a crank. The absolute angular velocity, ω_3, of the connecting link is important, however, and its variation with time may be plotted readily from values yielded by this construction. This velocity-time curve then may be differentiated graphically to produce an angular acceleration curve for the connecting link.

Unlike the conventional methods of graphical analysis of linkage systems, in this method no consideration need be given the instantaneous center of rotation of the connecting link. Whereas this fact alone does not always constitute an advantage of the method discussed herein, when the two cranks of a linkage approach parallelism, this instantaneous center may be located so far outside the limits of the work sheet as to be extremely inconvenient in executing the analysis.

War Broadens Scope of Designers

(*Concluded from Page* 54)

This should be relatively simple. The machine designer, after all, is a machine designer whether he designs adding machines, vacuum cleaners or screw machines. He works with the same materials, the same machine elements and the same knowledge. The only difference in each case is the final result, in one case an adding machine; in the second, a vacuum cleaner; and in the third, a screw machine.

Those machines can be reconditioned and rebuilt and only the engineer can carry the job through. American engineers do not shy away from a problem merely because they have never done it before. Designers can and will tackle such problems with the same ability and perserverance which has made this country pre-eminent in the world of machines.

Finally, but by no means least important, is the engineer's scope for inventiveness and ingenuity in developing new, and improving existing machines —for both direct and indirect war service. Such ideas arise out of maintaining a broad vision of what is required, of shortcomings of existing equipment, and from a drive and a will to win the war.

There is no standard system for producing these results, but certain conditions can be provided for stimulating them. In at least one large company, shifting of engineers from department to department has been found to stimulate the production of new ideas. A designer of turbines transferred to the engineering department concerned with motors brings with him a certain intimate background of experience that may, and often does, yield valuable advances. The scheme may not be scientific, savoring, as it does, of the method of the school boy chemist who mixes two chemicals together "to see what happens". But it gets results —and results are what count.

Correction

In the article "Eliminating Surging in Helical Springs" by A. M. Wahl in the April issue, an error occurred in Equation 10. The term π should have been π^2 to read $W=(\pi^2/2)\,d^2nr\gamma$.

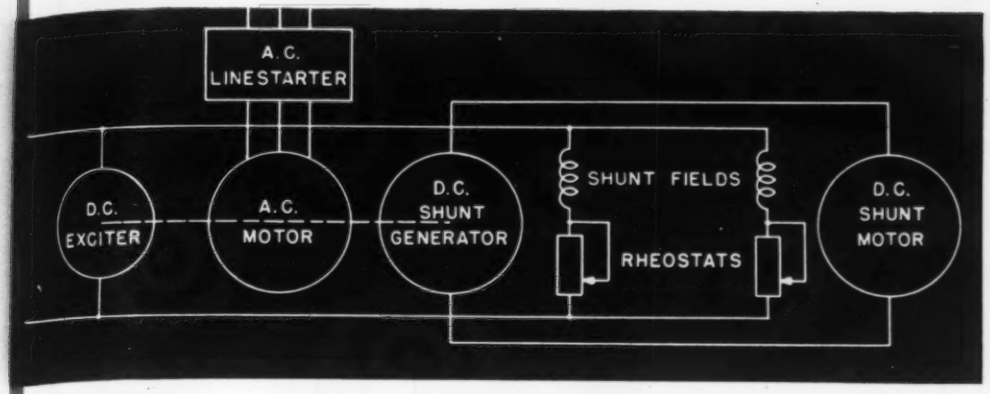


Fig. 1—Schematic diagram of conventional adjustable-voltage drive for speed control

Which Drive Serves Best for Speed Control?*

By G. A. Caldwell
Westinghouse Electric & Mfg. Co.

MOST machines driven by alternating-current motors with mechanical speed changers or by adjustable speed direct-current motors are limited in speed range to not more than 6 to 1. Mechanical drives which will give speed ranges of 10 to 1 or more may, in some cases, be obtained economically but in others the "adjustable-voltage" electrical drive is more economical and gives more flexible control.

This type of direct-current adjustable-speed drive has commonly been known as the variable-voltage or Ward-Leonard type. The term adjustable voltage is more descriptive of the system and will be used when referring to it in the following. The system has had the reputation of being elaborate and costly and being practical only for large and complicated machines. Recent developments, however, have greatly simplified the control so that overall costs compare favorably with those of other types.

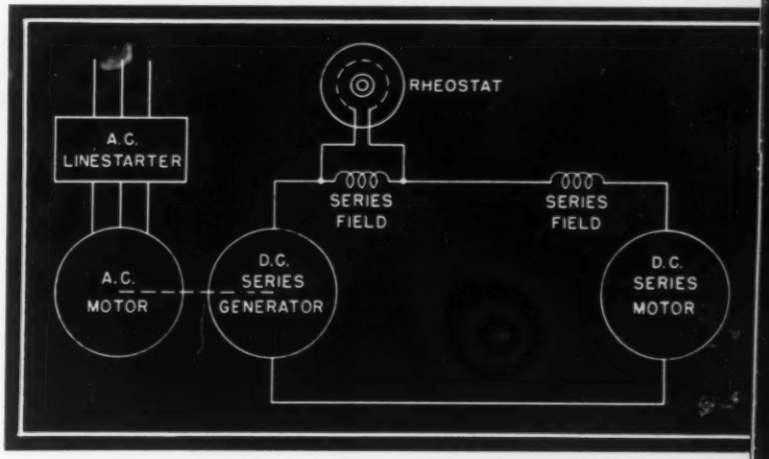
Direct-current adjustable-speed drive consists of a group of units that has as its basic unit a direct-current commutator-type driving motor which can have its speed varied by combination of field control on the motor and voltage control applied to the commutator. Because an adjustable-voltage direct-current source of power is required, some form of conversion unit to transform alternating-current power to direct-current power is used. There are five general groups which have been applied, only one of which is considered as generally known. These groups are:

Series variable-voltage
Self-excited adjustable-voltage
Conventional adjustable-voltage
Electronic adjustable-voltage
Wide speed range adjustable-voltage

The groups are listed in order of their relative simplicity and cost, the series variable-voltage being as a rule the cheapest and the wide speed-range the most expensive. Conventional variable-voltage is the most widely known and will be discussed briefly first; variations from this conventional adjustable-voltage drive will then be pointed out for each of the other types.

Conventional adjustable-voltage drive, as shown in *Fig.* 1, consists of a standard shunt-wound direct-current motor, a standard shunt or compound-wound direct-current generator and a separate direct-current source of excitation for both the generator and the motor. The main generator and ex-

Fig. 2—Diagram of a series variable-voltage drive



* From a paper presented at the Machine Tool Electrification Forum, East Pittsburgh, Pa., April 6-7, 1942.

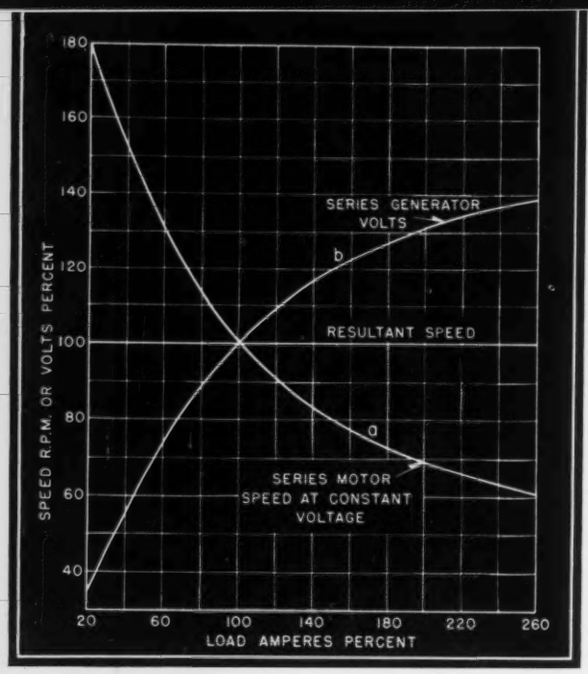


Fig. 3—Ideal combination of series motor and series generator showing constant resultant speed

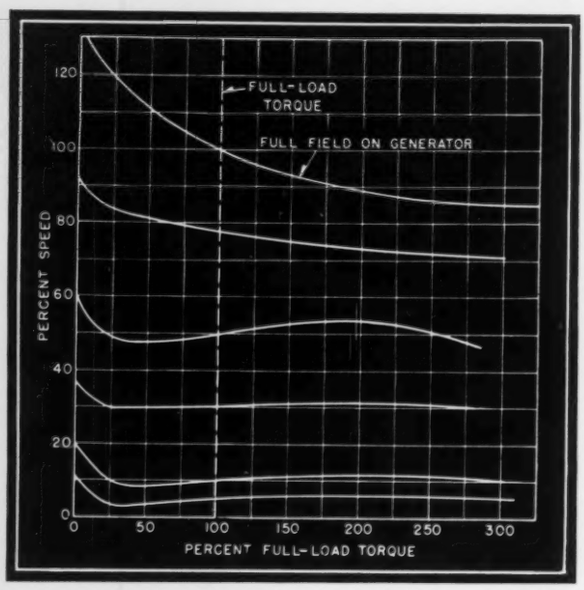


Fig. 4—Speed regulation of series variable-voltage drive with both motor and generator operating at full field

citer are usually built into a motor-generator set driven by an alternating-current squirrel-cage induction motor.

On this type of drive it is good practice to limit the speed range by voltage control to 10 to 1 as the speed regulation becomes excessive at low speeds and the drive has a tendency to stall on over-loads. On many applications it is possible to introduce a speed range of 4 to 1 by field control so that the total speed range may be as high as 40 to 1.

Conventional adjustable-voltage drive was originally developed for large machines where it was necessary to have frequent starting and stopping and where it was impractical to try to open the main armature circuits of the large motor equipment. Flexibility of this system, speed range obtainable and ability to use alternating-current power for a source of supply has caused it to be extended gradually to smaller motors rated as low as one horsepower. In small sizes the control equipment and exciter make up a large portion of the total cost of the drive whereas on the large equipments this portion of the drive is a small percentage of total cost.

The simplest form of drive yet developed is called the series variable-voltage drive and is shown in *Fig.* 2. The only control equipment required consists of a linestarter with its start and stop pushbuttons for the motor-generator set and a speed-adjusting rheostat. The exciter is eliminated by using a series wound direct-current motor and generator, and the control circuits are operated from the alternating-current power supply.

Gives Close Speed Regulation

Use of the series motor as a machine drive is limited because of its tendency to run away at no load. Its speed-torque curve when energized from a constand-voltage direct-current source is shown as curve *a* in *Fig.* 3. A series generator has a voltage-load characteristic that is similar to the series motor speed-torque characteristic with the exception that it is inverted. This is shown as curve *b* in *Fig.* 3. When a series generator supplies power to a series motor, the low voltage of the generator at light load holds down the inherent high no-load speed of the motor and the high voltage of the generator at heavy loads increases the speed of the motor at these loads. The resultant speed-torque curve of the system is indicated by the straight line in *Fig.* 3.

While this ideal is never achieved, actual results obtained are shown in *Fig.* 4. The top curve shows the speed torque characteristic obtained with both the motor and generator operating at full field. By shunting the generator field various speeds can be obtained with speed-torque curves as indicated. It will be noted that the speed-torque curves at the lower speed are practically flat except for the rather abrupt increase in speed that is obtained at light loads. While the theoretical speed regulation of the drive is high on the basis of the difference in speed between actual full-load speed and no-load speed, for all practical purposes on most drives the speed regulation is good because there is sufficient friction load in the machines to prevent actual increase in speed at no load. This drive still maintains the inherent characteristic of a series motor of high starting torque. With the rheostat set for one-tenth of maximum speed the drive will have a starting torque of at least six times full-load torque.

While the drive is normally used for a 10 to 1 speed range at continuous duty, it can be operated as low as one-twentieth of the maximum speed and still have good speed characteristics, as shown by the bottom curve. This low speed can be used for short periods for threading or inching operations.

In its simplest form as shown in *Fig.* 2 the drive

is started by starting the motor-generator set. This gives a soft start as the motor-generator set accelerates which in turn causes the series generator to build up its voltage and gradually to increase the torque on the direct-current driving motor. Stopping may be accomplished by drifting to a stop. Where it is necessary to have a quick stop, dynamic braking may be added. One circuit for dynamic braking is shown in *Fig.* 5. The motor is disconnected from the generator, the series motor fields reversed and connected across the motor armature with a resistor in series.

Another braking scheme is shown in *Fig.* 6. The series motor is equipped with a special braking field. For stopping, the motor is disconnected from the generator and the special field is connected across the motor armature terminals. A braking effect the same as obtained by reversing the series field of the motor is obtained.

Chief limiting factor in the size of equipment that can be built economically is the rheostat. Since this is connected in shunt with the generator series field and must shunt up to 95 per cent of the current from that field at the low operating speeds, the value of resistance in the rheostat at that point including leads must be less than one-twentieth of all the field resistance. To obtain the best results in the larger sizes, the rheostat should be mounted close to the motor-generator set or else have the wiring so arranged that the load resistance is in the generator field portion of the circuit rather than in the rheostat portion of the circuit.

Drive Eliminates Exciter

A second form of simplified adjustable-voltage drive in which the exciter has been eliminated is the self-excited shunt adjustable-voltage drive in which a shunt-wound direct-current motor and a shunt-wound generator are used, but the units are both connected so that they are excited from the generator as indicated in *Fig.* 7.

The generator in this system departs from the conventional design in that it must be stable at a materially reduced voltage when operating self-excited. By stable is meant that the generator will repeat and hold its voltage with a reasonable degree of accuracy or when considered from the generator saturation curve, the minimum stable point is that voltage at which the curve begins to part appreciably from a straight line. *Fig.* 8 shows that an ordinary generator when controlled by a rheostat of the usual design will be stable down to approximately 60 per cent of rated voltage at no load. This would allow operation only over an adjustable voltage range of slightly less than 2 to 1, insufficient for most applications. To widen this range the generator must be stable at some lower voltage. Because of limitation that will be mentioned later it is found that if the generator is stable to approximately one-fourth rated voltage that its range of adjustable voltage is sufficient for the self-excited adjustable voltage system.

Speed control of this drive is obtained by a rheostat which has two plates mechanically connected with one plate in the generator field circuit and the other in the motor field circuits. In the low-speed position, the motor is at full field and the generator at weak field. The rheostat is designed so that as resistance is cut out of the generator field to raise the generator voltage, the resistance in series with the motor field is increased and at

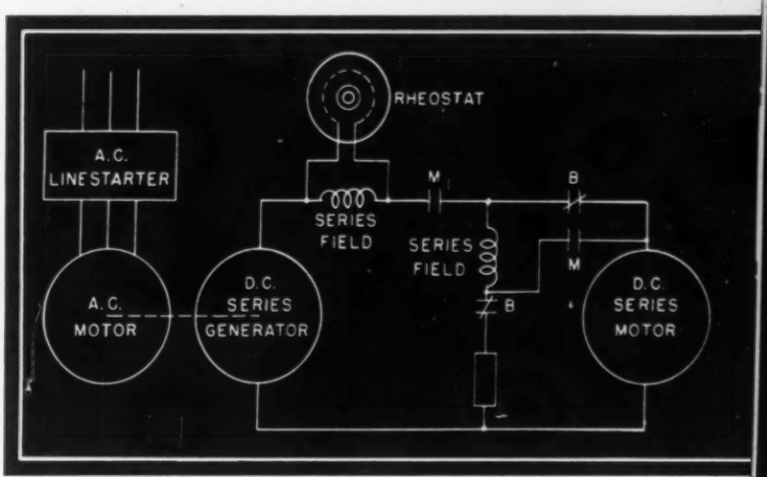


Fig. 5—Dynamic braking by reversing series motor field for series variable-voltage drive

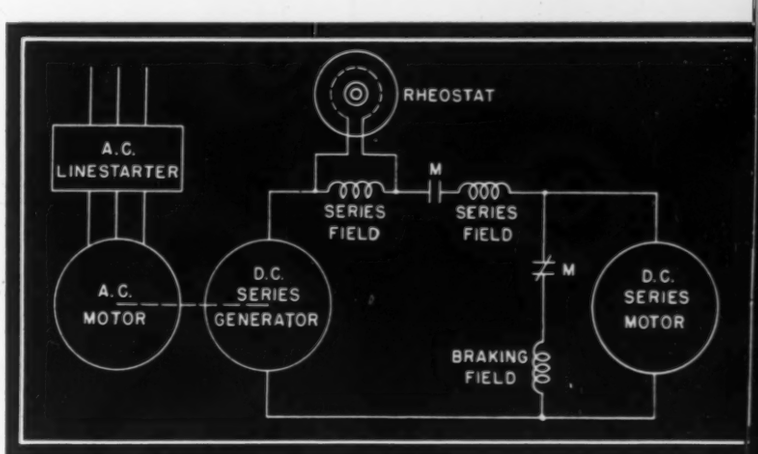
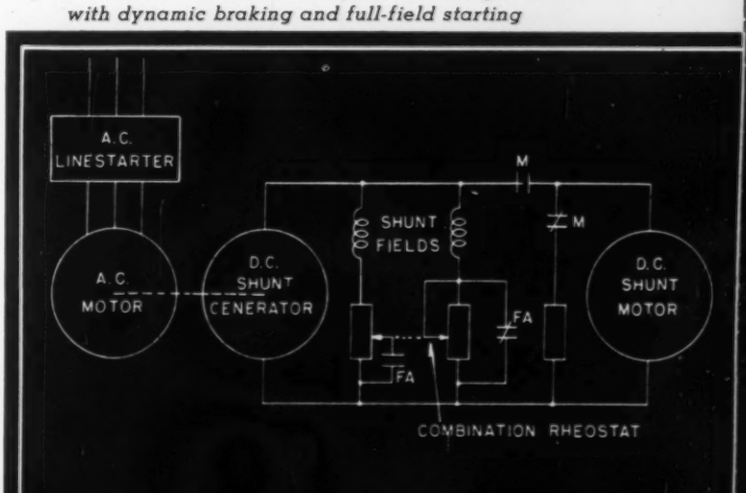


Fig. 6—Above—Diagram for series variable-voltage drive with dynamic braking by special braking field

Fig. 7—Below—Self-excited adjustable-voltage drive with dynamic braking and full-field starting



a rate to maintain full-field motor current. Since the motor is designed for full-field excitation at one-third normal voltage the rheostat losses are approximately three times those normally obtained on a shunt-wound direct-current motor, resulting in decreased efficiency and also in an increase in the cost of the rheostat itself.

Typical speed regulation curves for a self-excited adjustable-voltage drive are shown in *Fig.* 9. Regulation is best with the motor operating at full field and the generator at full voltage. This speed regulation is somewhat better than that obtained on the series variable-voltage drive at high speeds, but is not as good as the speed regulation obtained on the series variable-voltage drive at low speeds. Its starting or break-away torque at low speeds is more nearly in line with that obtained with the conventional system, being somewhat over 300 per cent full-load torque.

Because part of the speed range of this drive is obtained by shunt field control of the motor, it is constant horsepower over that portion of the range and constant torque over the portion of the range obtained by voltage control. It is therefore particularly suited to those loads which have a tendency to require high continuous running torques at low speeds and light continuous running torques at high speeds.

Inasmuch as this drive has both the motor and generator fields excited from the generator, the motor field is excited in the off position and dynamic braking can be obtained in the conventional manner by a resistor connected across the armature. Motor reversing also can be obtained by using a pair of reversing contactors. The normal control features such as inching, slowdown, etc., can be effected in much the same manner as on conventional variable-voltage control and is naturally more flexible than the series variable-voltage type of drive in obtaining these refinements. It is also more satisfactory on pulsating and reversing types of loads than the series variable-voltage drive.

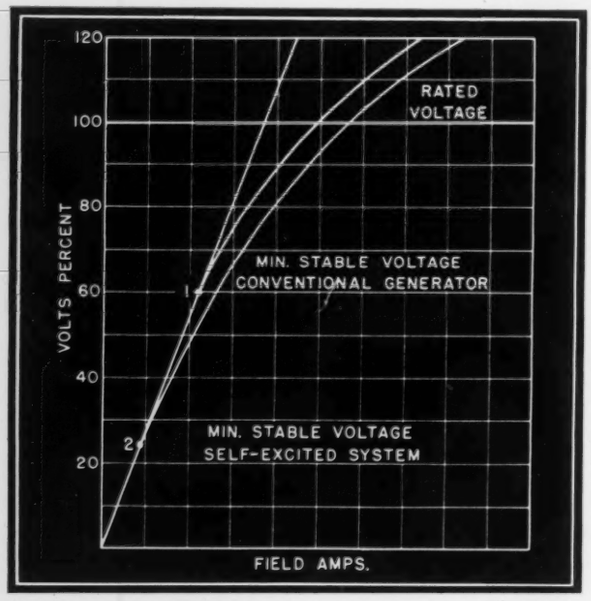
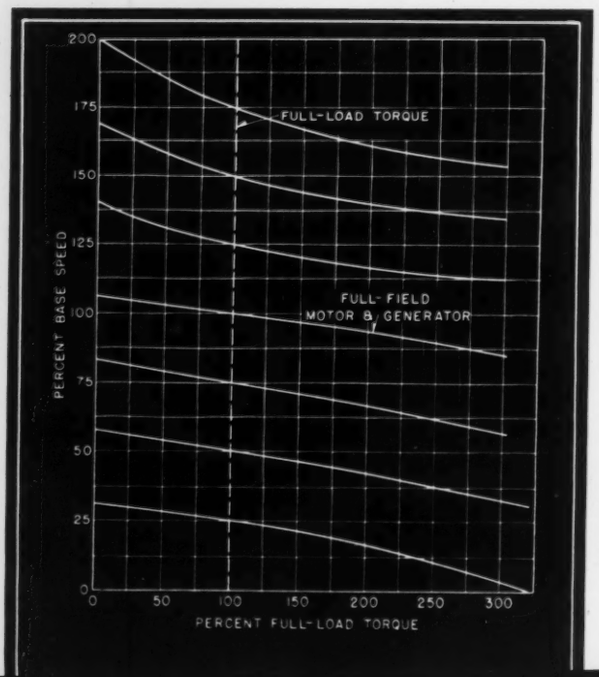


Fig. 8—Above—Saturation characteristics for direct-current generator showing stability down to 60 per cent of rated voltage at no load

Fig. 9—Below—Speed regulation of self-excited adjustable-voltage drive. Speed regulation is best when motor is operating at full field and generator at full voltage



Extra Speed Range May Be Needed

It should not be assumed that the exciter must be eliminated to simplify the adjustable-voltage type of drives. On applications where the requirements primarily involve speed range in excess of that which can be obtained with the drives already mentioned, the overall system can be simplified even though an exciter is used.

To eliminate all mechanical gear shifting in an automatic screw machine, a conventional variable-voltage drive was applied consisting of a small direct-current motor with power supplied from a motor-generator set as shown in *Fig.* 10. In this particular case a rectox unit furnishes excitation for the motor and generator instead of separate exciter as it is more convenient to mount. The motor is supplied with a shunt field operating continuously at full field value and the entire speed range of 25 to 1 is obtained by voltage control. This was done primarily to simplify control operation. The direct-current generator is equipped with two fields, one varying the speed of the motor by changing the generator voltage and a second connected differentially to the other to permit bringing the generator output voltage down to a low value. This even bucks residual voltage if necessary and at the same time does not require an excessive amount of resistance in the main generator field rheostats. A third field on the generator is a series field which gives excitation proportional to load and compensates for the *IR* drop of the system for good regulation at all speeds.

A selector switch and a group of duplicate rheo-

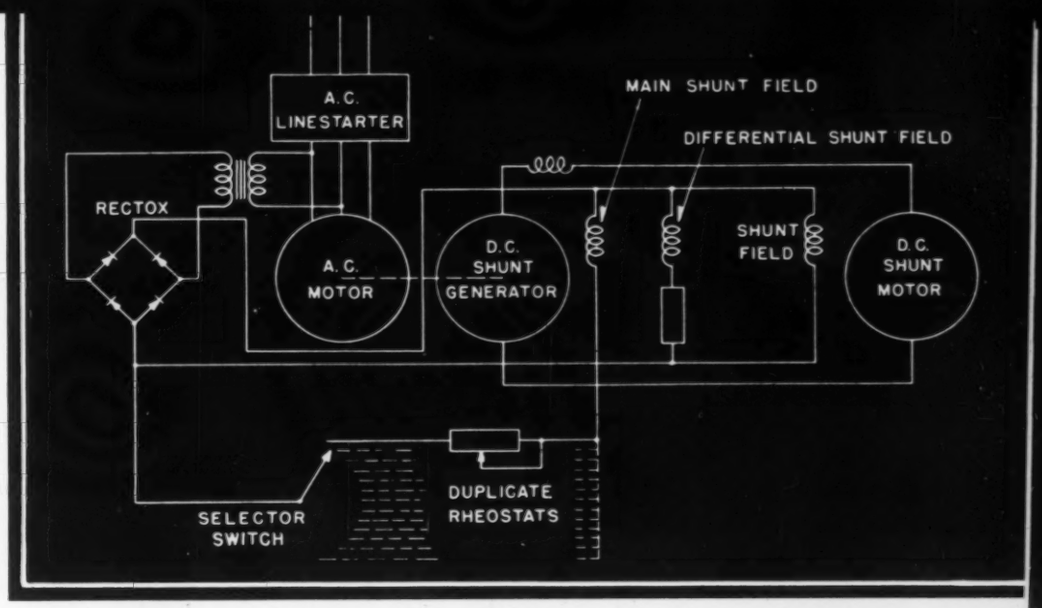


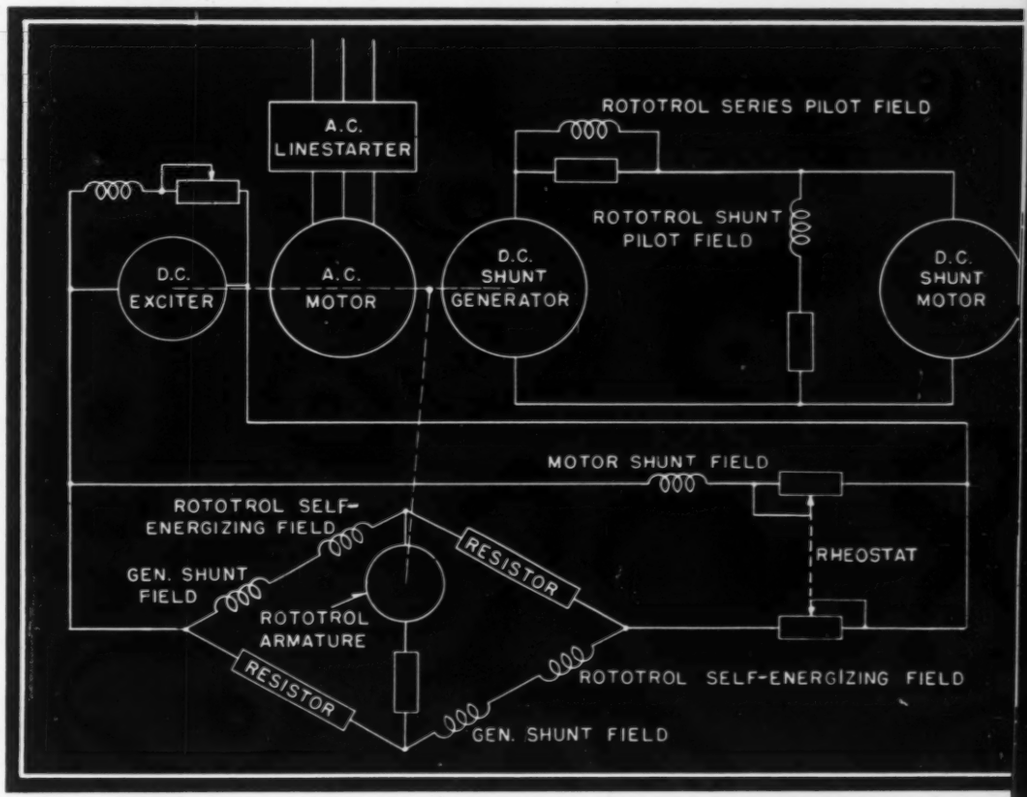
Fig. 10—Above—Conventional adjustable-voltage drive with speed selection

stats are connected in series with the main generator field. By adjusting these rheostats to different values of resistance, different speed is obtained for each point of the selector switch. Each rheostat has sufficient resistance to give the entire speed range of the equipment. The selector switch is mechanically connected to the machine and as the machine changes from one operation to the other the selector switch is mechanically rotated to the next point.

Wide speed range adjustable-voltage drive makes use of the units normally used on a conventional variable-voltage control with the addition of a regulating generator called a Rototrol unit. Any direct-current adjustable-voltage scheme operating over speed ranges in excess of 10 to 1 by variable-voltage control require compensation for certain characteristics at low speed which are not important at high speed. The two most important factors are the residual voltage of the generator and the *IR* drop of the system.

Most generators have a residual voltage of between three and four per cent of their normal operating voltage. This means that the no-load speed of the motor which is being driven by such a generator by variable-voltage control is limited to a no-load speed range of about 25 to 1 since the residual voltage will not permit a voltage lower than itself to exist. For voltage ranges in excess of 25 to 1 it is necessary to make some arrangement to overcome this residual voltage. Also, since the residual is a function of the previous magnetic history of the generator, it is necessary that the equipment used to overcome the residual must be able to determine the actual conditions which exist. A diagram of the wide speed range drive is shown in *Fig.* 11.

Fig. 11—Below—Schematic diagram for wide speed range drive



A fifth general classification of variable-voltage drives uses the conventional direct-current motor but utilizes an electronic rectifier for its source of power instead of a motor-generator set. Experimental units have been in use for several years on various types of applications, and there is no doubt that there will be further developments and application of this type of variable-voltage control. At the present time the equipment is limited in size and speed range. Also it is more expensive than the conventional variable-voltage control using a motor-generator set. The normal unit uses two electronic tubes to give single-phase full-wave rectification with power supplied to the tubes by a

suitable primary transformer. In addition to the main circuit rectifier tubes there is a set of smaller tubes used to give direct-current for the field circuit.

This type of control will probably have its greatest appeal to those manufacturers who have a need for a fairly wide speed range, but where the mounting of a motor-generator set is objectionable either from the space standpoint or from the point of vibration. Vibration problem is especially important on certain types of grinders. The greatest disadvantage of this equipment at present is its high cost and the fact that maintenance men are not familiar with it.

Need Ventilation for Constant Torque

When applying variable-voltage drives having fairly wide speed ranges, it is frequently assumed that the motors deliver constant torque. That is not quite true due to the fact that a motor running at low speed does not ventilate as well as a motor running at higher speeds and therefore the losses in the machine are not dissipated to the same extent. Consequently a motor carrying constant current over a wide range of speed will run hotter at low speed than at high speed. Although this effect will vary with the size and design of the motor the approximate relation of torque rating to the speed of the motor is shown in *Fig.* 12. These curves are based on a motor running at its rating continuously at a 40-degree rise and its base full-field speed. The addition of any protective covering increases the temperature rise at any given speed. On many larger motors, where it is desired to have them well protected and at the same time operate over wide speed range, forced ventilation may be easily justified as it provides normal ventilation of the motor at any speed and it is therefore really a constant torque application.

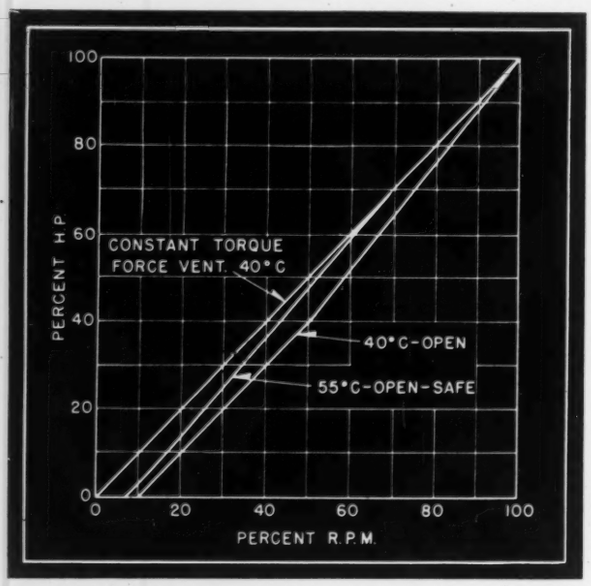


Fig. 12—Relation of horsepower and speed of adjustable-voltage motors

A summary of the types of variable-voltage drives is shown in the following table, giving comparisons on basis of simplicity, cost, speed range and speed regulation. The series variable-voltage drive rates first in regard to simplicity and cost. However, it is limited in its speed range and does not have as good voltage regulation as some of the other drives. It is particularly adaptable to drives which are constant torque in their application and where high starting torques are necessary. It is not suitable for rapid-fluctuating loads nor is it particularly suitable for rapid-reversing load.

Comparison of Various Drives

Type of Drive	Simplicity	Cost	Speed Range Ratio—Voltage Control (Constant torque)	Field Control (Constant horsepower)	Total	Speed Regulation
Series Variable Voltage	1	1	10:1	0	10:1	4
Self-Excited Adjustable Voltage	2	2	3:1	4:1	12:1	4
Conventional Adjustable Voltage	3	3	10:1	4:1	40:1	2
Electronic Adjustable Voltage	4	4	10:1	4:1	40:1	3
Wide Speed-Range Adjustable Voltage	5	5	60:1	2:1	120:1	1

Self excited adjustable voltage drive rates next to the series variable voltage in regard to simplicity and cost and has comparable speed regulation. It has approximately the same speed range and can be used for the same general type of applications but it does have the advantage in that it can be used more readily on rapidly fluctuating loads. Various control features can be more easily applied. The drive also is well adapted to drives that require high torques at low speeds as the drive operates over a 4 to 1 speed range at constant horsepower.

Conventional adjustable-voltage drive is applied on certain types of drives requiring speed ranges in excess of what can be obtained on simplified drives above. The drive is naturally more elaborate and expensive but in turn it has a better speed regulation and is more flexible when it comes to adding special control features.

Electronic adjustable-voltage control is more expensive and usually more complicated than the conventional adjustable voltage control drive and has about the same speed range although the simplified form has poor speed regulation. The principal advantage is that the motor-generator set with its vibration and mounting problem is eliminated.

Wide speed-range adjustable-voltage drive is naturally more elaborate and more expensive than the other drives but is justified by the fact that the regulating generator gives it a much wider speed range and better speed regulation than any other form of adjustable voltage drive.

Designing High-Pressure Vessels and Piping

By Joseph Marin
Pennsylvania State College

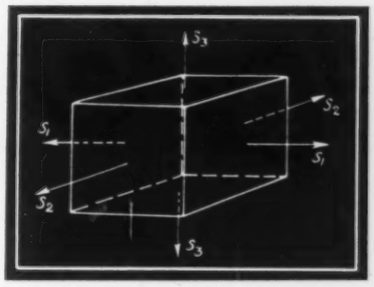
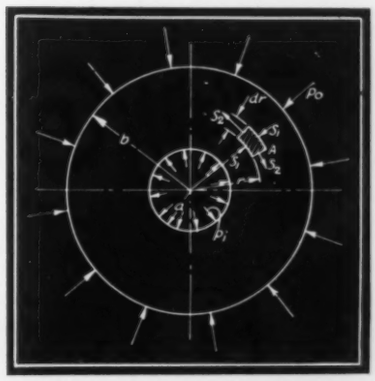


Fig. 1—Above—Element of cylinder wall subject to triaxial principal stresses

Fig. 2—Below—Stresses produced on an element in a thick-walled cylinder subject to internal and external pressures



IN THE previous article of this series, pressure vessels and piping were considered for applications in which the pressures are small. For these relatively low pressures the required wall thickness is small compared to the other dimensions. In the case of a thin-walled cylinder the longitudinal and circumferential stresses are assumed uniform throughout the wall and the radial stress is considered negligible. These assumptions are allowable provided the wall thickness of the vessel is not more than about one-tenth the radius. When the pressure is high the determination of the stresses can no longer be made by the elementary methods of stress analysis since the wall thickness is of such magnitude that the stresses are not uniform throughout the wall and the radial stress can no longer be neglected.

Strain-Energy Theory Is Used

There are many industrial applications of thick-walled cylinders subjected to high internal or external pressures, or both. Hydraulic presses and guns are two important applications. In some equipment the use of high-pressure piping is necessary. Piping of this type is not only subject to circumferential, longitudinal and radial stresses due to the internal pressure, but also to stresses produced by thermal expansion, torsion, bending and transverse shear. The purpose of this article is to consider the "combined stress effect" in these as well as other applications of thick-walled pressure cylinders.

DETERMINING WALL THICKNESS: In determining the wall thickness required, the *strain-energy theory of failure* will be used instead of the distortion energy theory as previously used. The reason for this is that most of the applications discussed in this article involve triaxial stresses and there is no experimental proof of the distortion energy theory for this type of stress. In fact, for three equal tensile principal stresses the distortion energy theory gives the impossible result that a material has infinite strength. The strain energy theory gives, for three-dimensional stresses, a reasonable result and, for two-dimensional stresses, the results agree closely with the distortion-energy theory. It has also the desirable feature of giving results

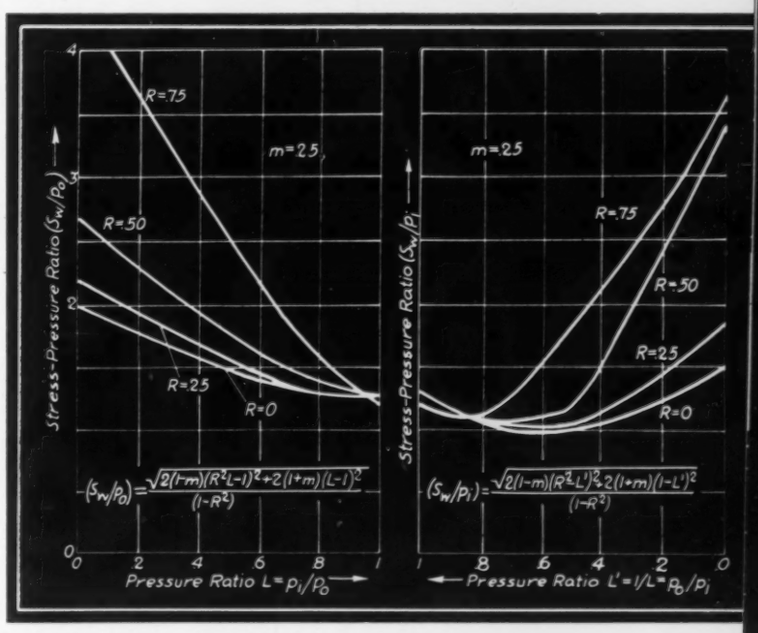


Fig. 3—Pressure ratios plotted against stress-pressure ratios for different values of R. Poisson's ratio is .25

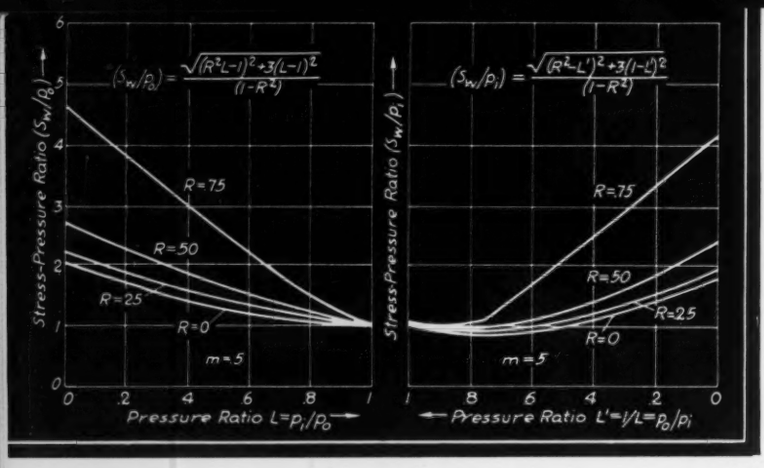


Fig. 4—Pressure ratios plotted against stress-pressure ratios for different values of R, Poisson's ratio being .5

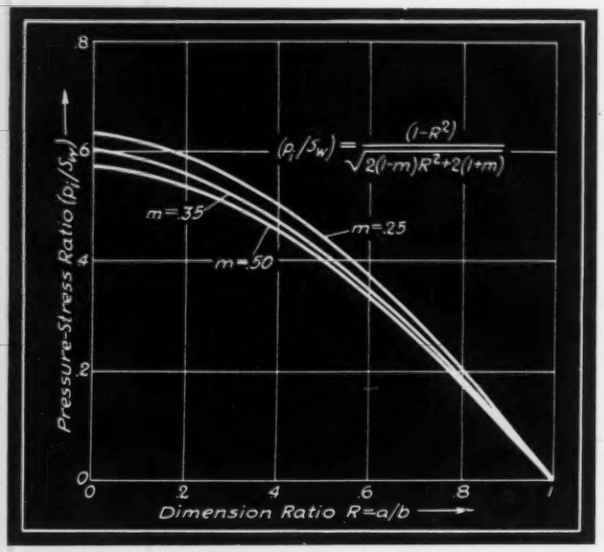


Fig. 5—Variations in pressure-stress ratio with change in radius ratio for different values of Poisson's ratio

on the side of safety. This is particularly desirable in a problem for which little data is available.

The strain energy theory is based on a consideration of the total energy of deformation. For an element subject to three triaxial principal stresses, as shown in *Fig.* 1, the strain energy is

$$U=\frac{1}{2E}[S_1^2+S_2^2+S_3^2-2m(S_1S_2+S_2S_3+S_1S_3)] \quad \ldots\ldots (1)$$

where E is the modulus of elasticity, m is Poisson's ratio and S_1, S_2 and S_3 are the principal stresses.

The allowable value of the strain energy U is that corresponding to the tensile allowable stress S_w. This is found from Equation 1 by placing $S_2 = S_3 = 0$ and $S_1 = S_w$. Doing this, the value of the allowable strain energy is

$$U_w=\frac{S_w^2}{2E} \quad \ldots\ldots (a)$$

[1] For a derivation of these stress values see F. B. Seely's *Advanced Mechanics of Materials*, John Wiley & Sons, or S. Timoshenko's *Strength of Materials*, Vol. 2, Van Nostrand Co., 1941.

Equating U to U_w in Equations 1 and *a*, the working stress, in terms of the principal stresses, by the strain energy theory is defined by the following equation:

$$S_w^2=S_1^2+S_2^2+S_3^2-2m(S_1S_2+S_2S_3+S_1S_3) \quad \ldots\ldots (2)$$

In applying this theory to the design of high-pressure equipment it will be necessary first to select the critical element. This element is located at the point where yielding would begin according to this theory. It will be the element for which the strain energy U in Equation 1 is a maximum. For example, in *Fig.* 2 there is an element, at some distance r from the center, for which U is a maximum. This element will be located by inspection or by using the calculus condition for maximum as explained in the following examples.

BIAXIAL STRESSES: For the thick-walled cylinder subject to internal and external pressures shown in *Fig.* 1, stresses are produced for a point such as *A* in the radial and circumferential directions. If the cylinder is supported in such a way that the longitudinal load produced by the internal pressure is resisted by the supports, then the stresses produced are those shown in *Fig.* 2. It has been shown by the theory of elasticity that the values[1] of these stresses are

$$\left.\begin{aligned} S_1&=\frac{a^2p_o-b^2p_o}{b^2-a^2}-(p-p_o)\left(\frac{a^2b^2}{b^2-a^2}\right)\frac{1}{r^2}=A-\frac{B}{r^2}\\ S_2&=\frac{a^2p_i-b^2p_o}{b^2-a^2}+(p_i-p_o)\left(\frac{a^2b^2}{b^2-a_o}\right)\frac{1}{r^2}=A+\frac{B}{r^2}\end{aligned}\right\} \quad \ldots (b)$$

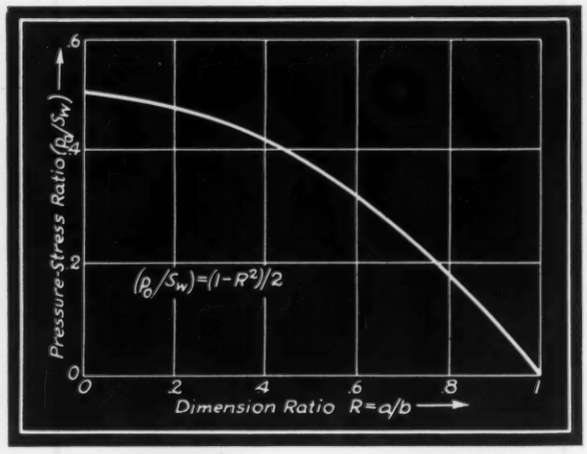
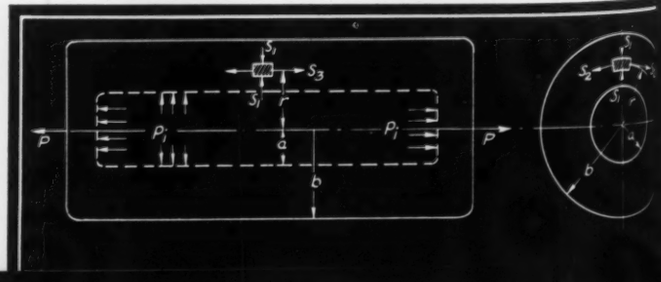


Fig. 6—Above—Values of dimension ratio with change in pressure-stress ratio

Fig. 7—Below—Triaxial stresses on element in closed cylinder with internal pressure



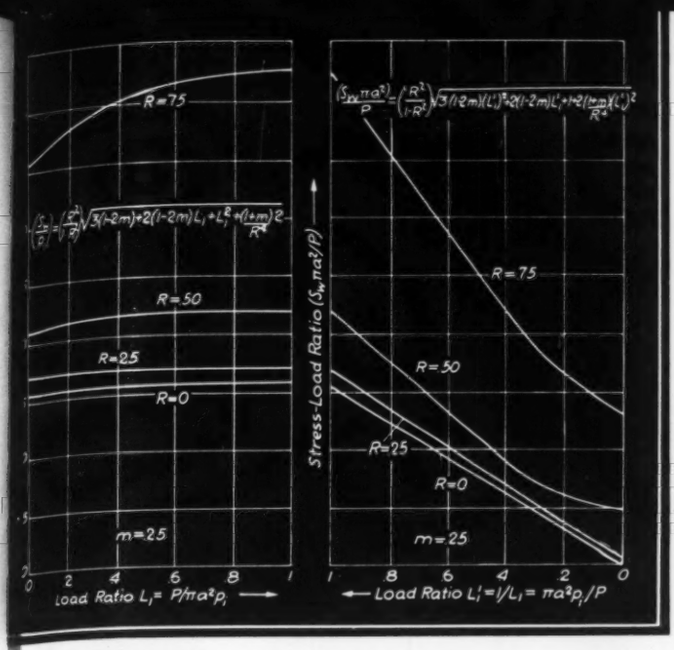
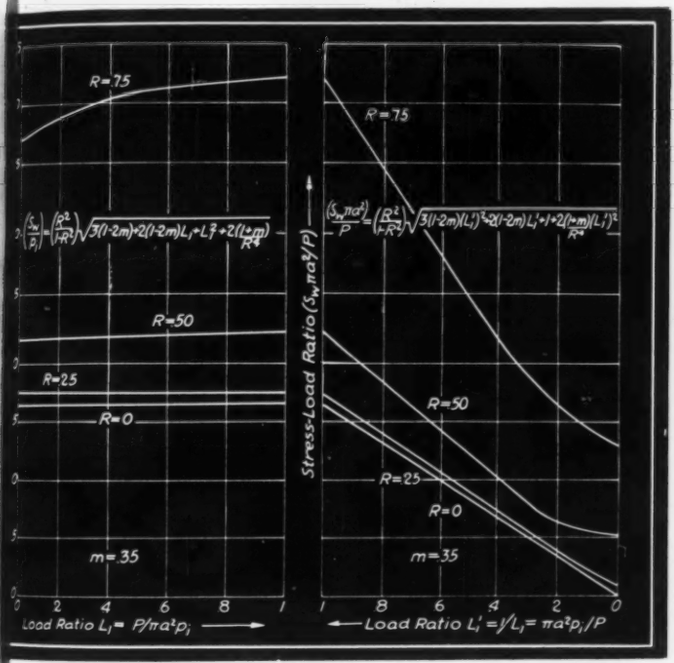


Fig. 8a—Variations in stress-pressure and stress-load ratios with load ratio for Poisson's ratio of .25

Fig. 8b—Below—Curves similar to Fig. 8a except Poisson's ratiois .35



where

$$A = \frac{a^2 p_i - b^2 p_o}{b^2 - a^2} \quad \text{and} \quad B = (p_i - p_o)\left(\frac{a^2 b^2}{b^2 - a^2}\right) \qquad \ldots\ldots (c)$$

In Equations b, p_o and p_i are the internal and external pressures respectively. The internal and external radii of the cylinder are a and b respectively, as shown in *Fig.* 2. Placing the values of the stresses from Equations b in Equation 1, the strain energy for the element at A (located at a distance r from the center, as shown in *Fig.* 2) is

$$U = \frac{1}{2E}\left[2(1-m)A^2 + 2(1+m)\frac{B^2}{r^4}\right]$$

By an inspection of this equation the strain energy U is a maximum for a minimum value of r. That is, for $r = a$. This gives for the maximum value of U

$$U_{max} = \frac{1}{2E}\left[2(1-m)A^2 + 2(1+m)\frac{B^2}{a^4}\right] \qquad \ldots\ldots (d)$$

where A and B are as defined in Equations c.

Placing the strain energy value in Equation d equal to the allowable value $S_w^2/2E$,

$$S_w^2 = 2(1-m)A^2 + 2(1+m)\frac{B^2}{a^4} \qquad \ldots\ldots (e)$$

Equation e can be written in a form that permits the plotting of design charts by substituting values of A and B from Equations c in Equation e and rearranging terms. This yields the following expression for the load-stress ratio, S_w/p_o, in terms of the required dimension ratio $R = a/b$:

$$\left(\frac{S_w}{p_o}\right) = \frac{\sqrt{2(1-m)(R^2L-1)^2 + 2(1+m)(L-1)^2}}{(1-R^2)} \qquad (3)$$

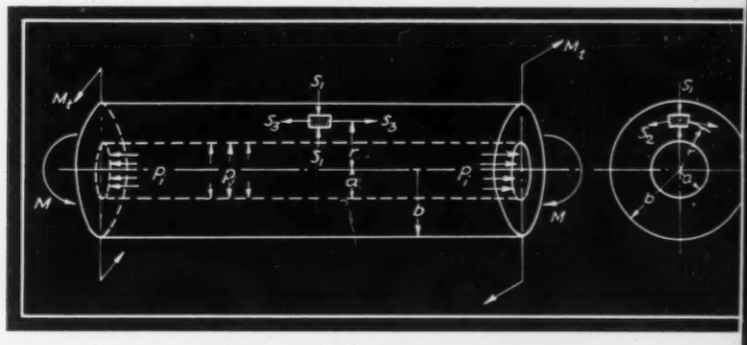
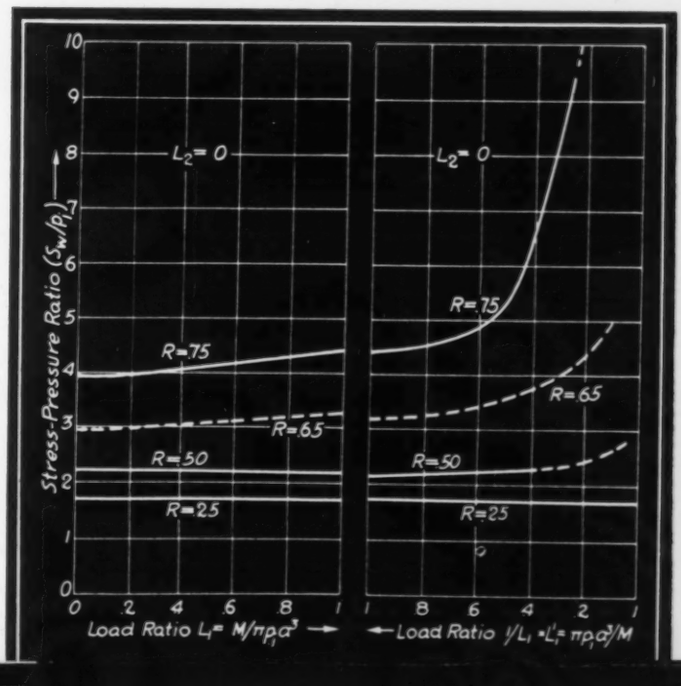


Fig. 9—Element in wall pipe subject to internal pressure, thermal expansion, bending and twisting

Fig. 10—Below—Chart for high pressure piping when $L_2 = 0$. Supplementary charts for various values of L_2 are shown in succeeding illustrations



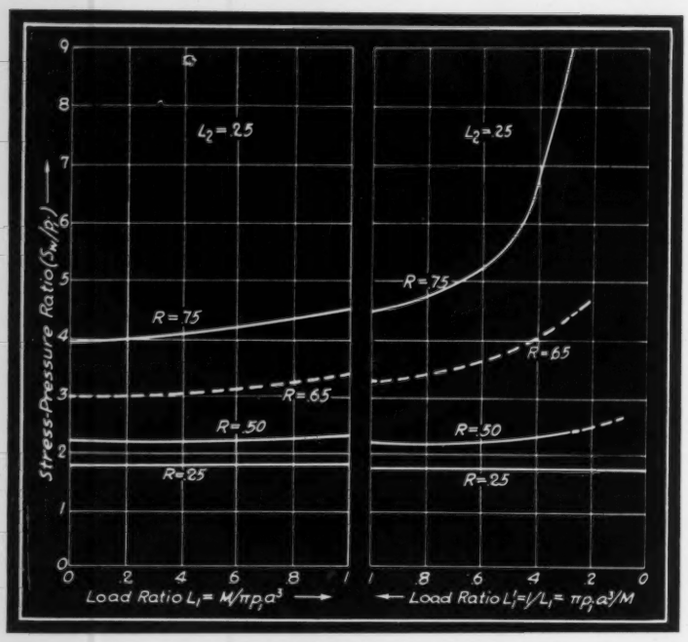


Fig. 11—Design chart for L_2=.25

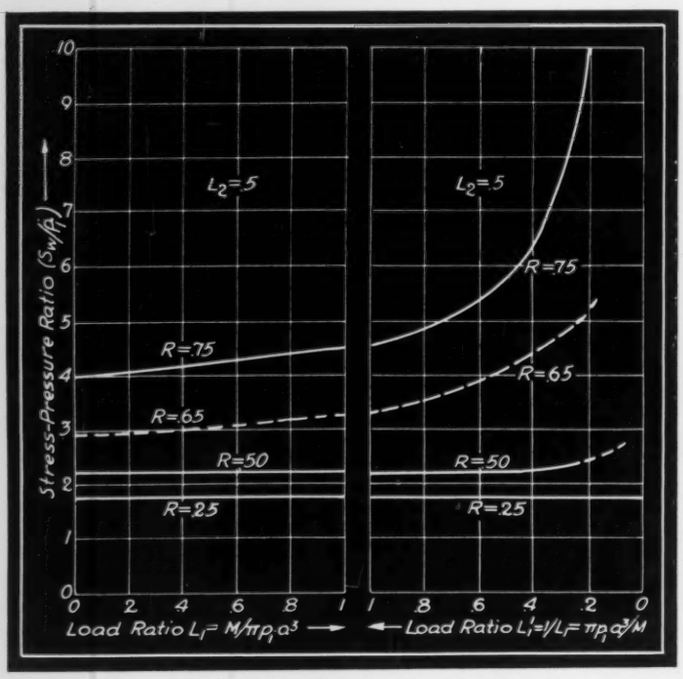


Fig. 12—Design chart for L_2=.5

where $R = a/b$ and $L = p_i/p_o$.

The variation between the load-stress ratio, S_w/p_o, and the load ratio $L = p_i/p_o$ is shown in *Figs.* 3 and 4 for different values of the dimension ratio $R = a/b$. *Fig.* 3 is plotted for the value of Poisson's ratio = .25. This value represents an appropriate average for ductile materials. *Fig.* 4 gives a plot of Equation 3 for a value of Poisson's ratio = .5. No such value has ever been reported for an engineering material but such a value gives the design chart as would be determined using the distortion energy theory. *Figs.* 3 and 4 can be used to determine the required wall thickness in the following manner: Knowing the pressures and the working stress, the x and y ordinates in *Fig.* 3 or 4 are known. By interpolation the value of $R = a/b$ can then be selected. Since the value of a is governed by some other design consideration, the outer radius $b = a/R$ is known and hence the wall thickness is determined.

For *thick-walled cylinders subject to internal pressure only,* such as hydraulic presses and some piping, Equation 2 can be used for determining the wall thickness. This can be done by noting that Equation 3 can be written:

$$S_w = \frac{\sqrt{2(1-m)\,R^2p_i - p_o)^2 + 2(1+m)(p_i - p_o)^2}}{(1-R^2)} \quad \ldots\ldots (3a)$$

Placing the external pressure $p_o = 0$ in Equation 3a and dividing both sides of Equation 3a by p_i,

$$\left(\frac{p_i}{S_w}\right) = \frac{1-R^2}{\sqrt{2(1-m)R^2 + 2(1+m)}} \quad \ldots\ldots (4)$$

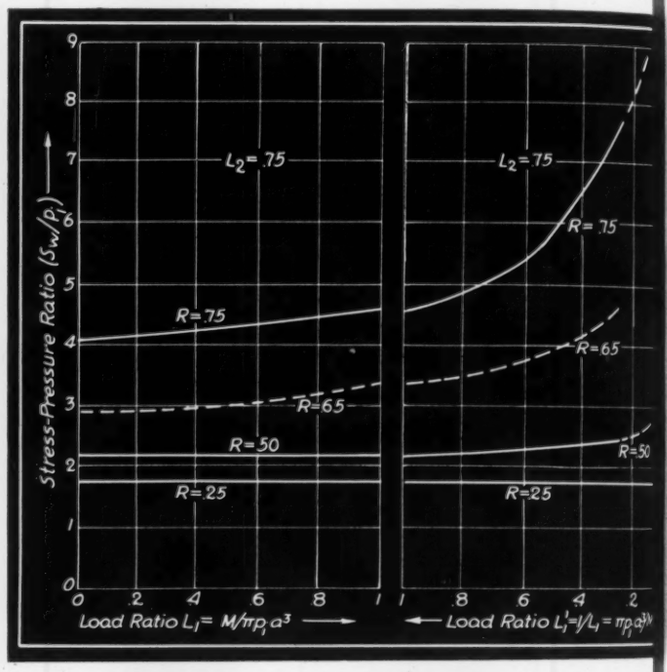
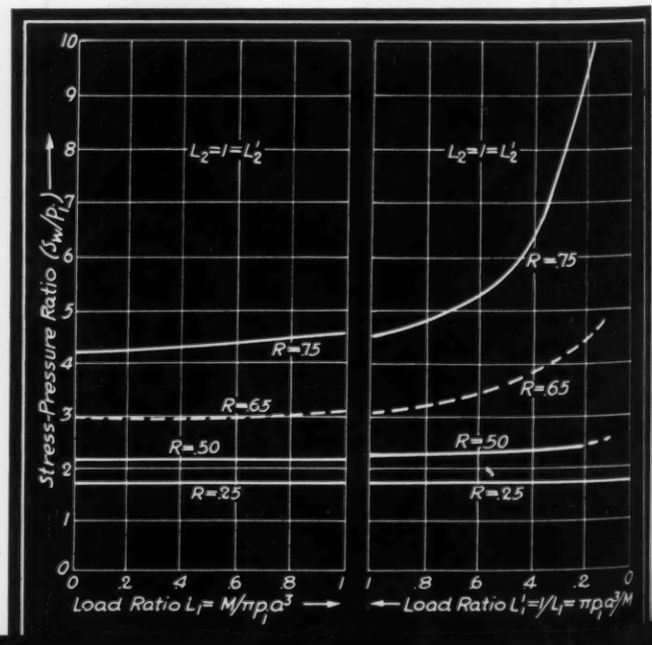


Fig. 13—Design chart for L_2=.75

Fig. 14—Below—Design chart for L_2=1



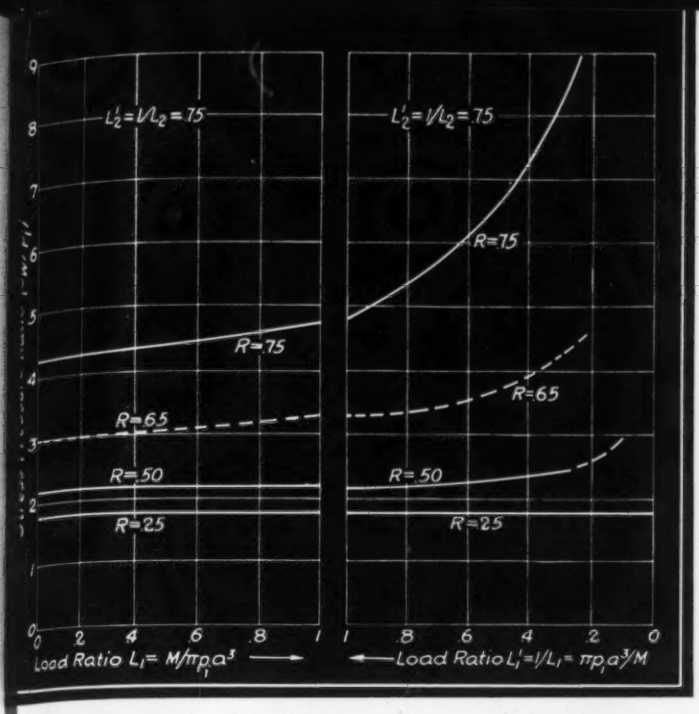


Fig. 15—Design chart for $L_2'=.75$

The variation in the stress-load ratio, p_i/S_w, with change in dimension ratio R is shown in *Fig.* 5 for different values of m. Placing $m = .5$ in Equation 4 gives the wall thickness using the distortion energy theory. *Fig.* 5 can be used for determining the required dimension ratio $R = a/b$ for a known load ratio p_i/S_w. With the inner radius a determined by other design considerations, the value of b can then be found and hence the required wall thickness.

Thick-walled cylinders are sometimes subject to external pressures only. The required value for the wall thickness is then determined from Equation 3 by placing $p_i = 0$ or $L = 0$. The load-stress ratio then becomes

$$\left(\frac{p_o}{S_w}\right) = \frac{1-R^2}{2} \qquad \ldots\ldots (5)$$

The variation in the dimension ratio R with change in pressure, as represented by the load ratio, p_o/S_w, is shown in Fig. 6. With the value of R selected from this diagram the outer radius b can be found, since a is usually known. The wall thickness is then $t = b - a$.

TRIAXIAL STRESSES: In some thick-walled pressure cylinders, in addition to internal pressure, there is an axial stress produced in the direction of the longitudinal axis. This stress is produced by a longitudinal tensile load caused by the internal pressure if the ends of the cylinder are closed, or by a superimposed axial tensile or compressive load, as shown in *Fig.* 7. The stresses on an element at A in the cylinder are, under this loading,

$$\left.\begin{aligned} S_1 &= k_1 p_i\left(1-\frac{b^2}{r^2}\right) \\ S_2 &= k_1 p_i\left(1+\frac{b^2}{r^2}\right) \\ S_3 &= k_1 p_i \pm P k_2 \end{aligned}\right\} \qquad \ldots\ldots (6)$$

where the following relations are

$$k_1=\frac{a^2}{b^2-a^2} \quad \text{and} \quad k_2=\frac{1}{\pi(b^2-a^2)} \qquad \ldots\ldots (f)$$

Placing the values of the stresses from Equations 6 in Equation 1, the strain energy for the element at A is

$$U=\frac{1}{2E}\left(\frac{p_i a^2}{b^2-a^2}\right)^2\left[3(1-2m)\pm 2(1-2m)L_1+ L_1^2+2(1+m)\left(\frac{b}{r}\right)^4\right] \qquad \ldots\ldots (g)$$

where

$$L_1=\frac{P}{\pi a^2 p_i}$$

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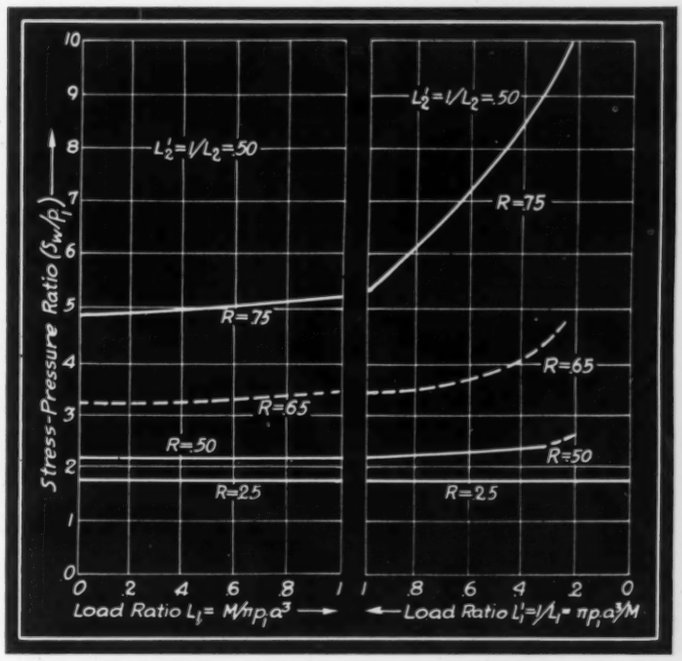
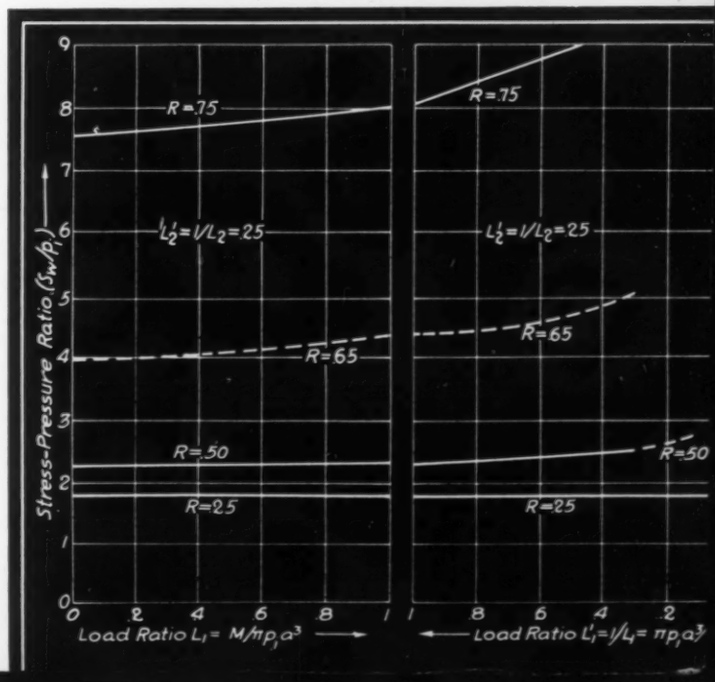
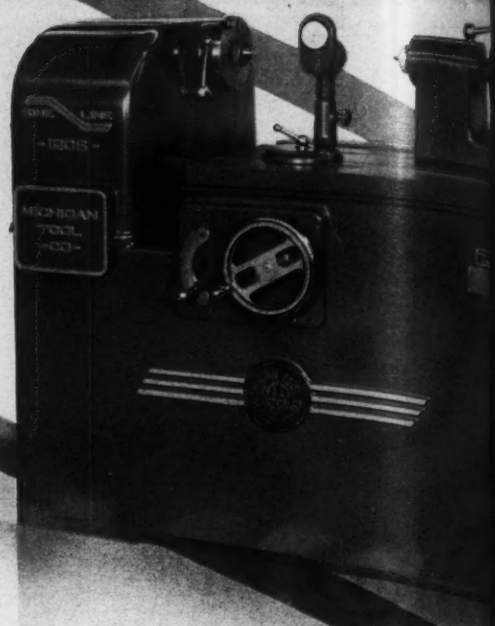


Fig. 16—Design chart for $L_2'=.5$

Fig. 17—Design chart for $L_2'=.25$





Below—Sensitivity and accuracy of Federal thread gage is in large part attributable to the fact that the upper sensitive contact point as well as the lower locating points are spring mounted and free from friction. Capable of being set accurately back of the work and also to allow for heads, shoulders, etc., the back stop is adjustable vertically, laterally and angularly

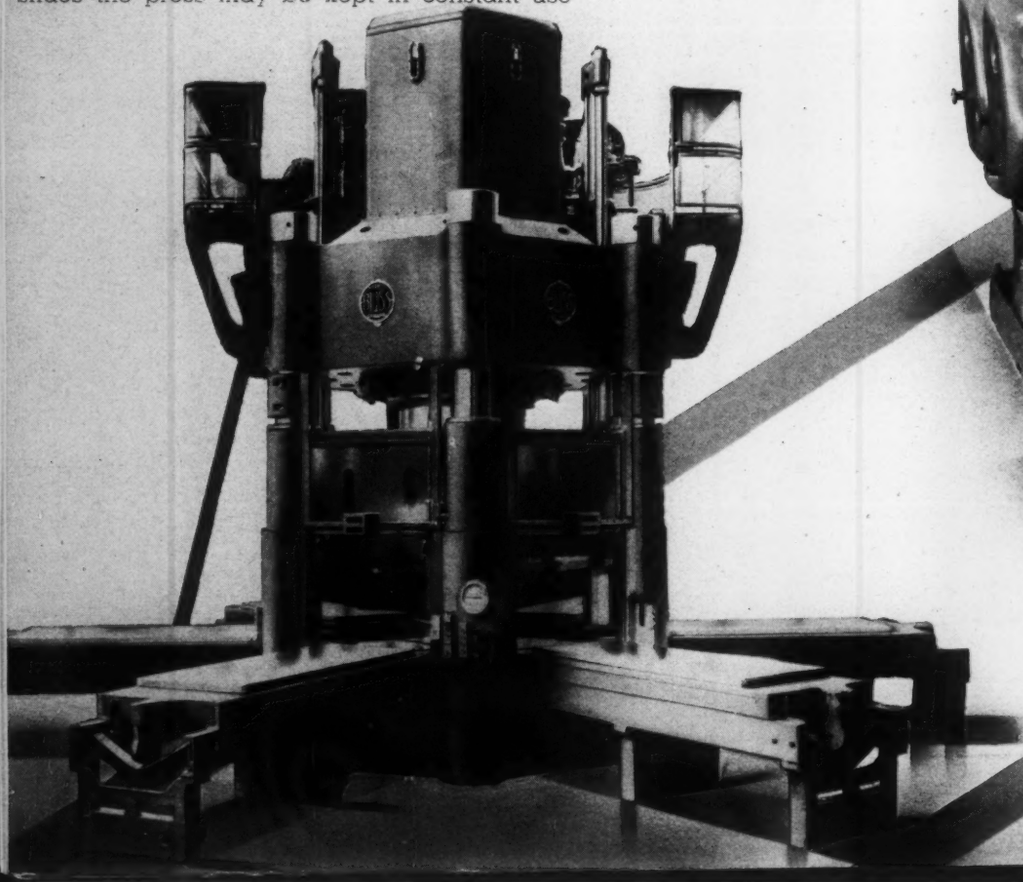
Above—Of the adjustable [illegible] spiral gear-checking machine elim[illegible] rolls, disks or lead screws. Indicator [illegible] swung from left to right for checking wi[illegible] gear tooth. Indicator is moved along fa[illegible] to th[illegible] backhand tool on front of ma[illegible]

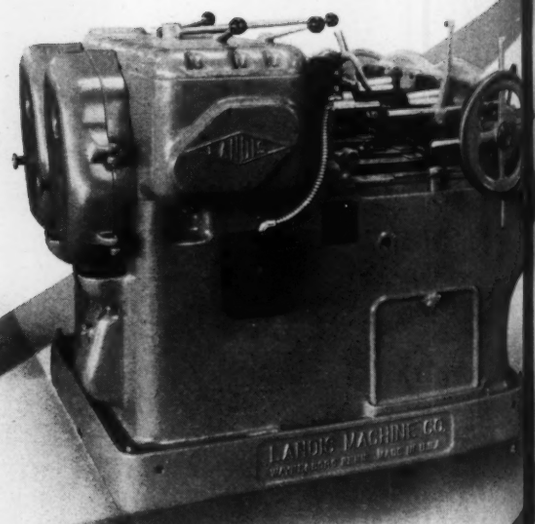
Above—High-speed motor-driven flywheel transmitting power through multiple V-belts to a gear system running in a bath of oil constitute the complete drive assembly of Cleveland press. All elements are fully enclosed and mounted for easy removal in the crown of the machine, eliminating all overhanging brackets

New Produc[illegible]

(For new mac[illegible] see P[illegible]

Below—By rotating the rubber pad holder of Bliss hydraulic press to meet the incoming die slide, greater production flexibility in complying with the demands of the aircraft industry is provided. Self-selective, interlocking control insures safe and fast operation. By use of six slides the press may be kept in constant use

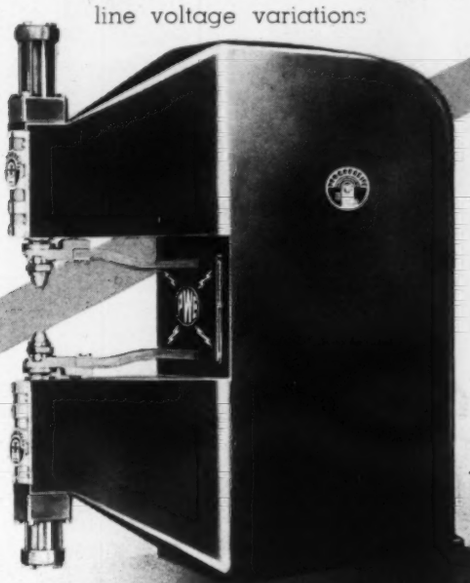


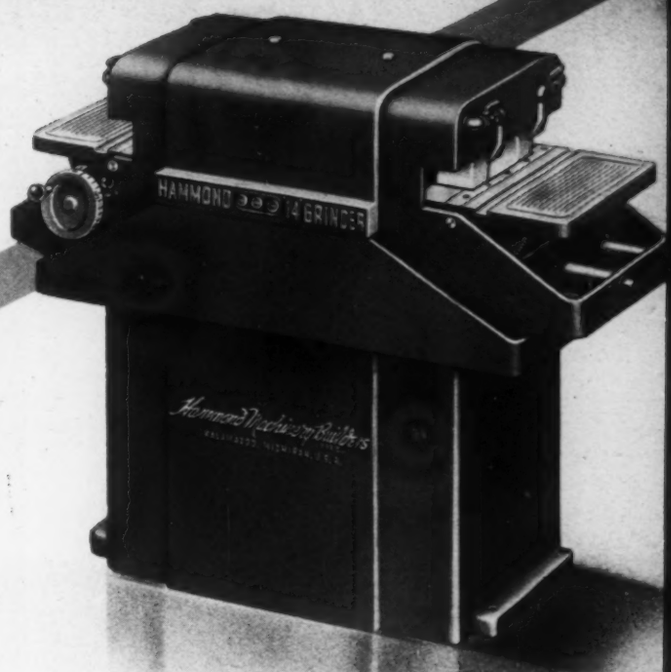


Above—Designed for removing exc[illegible] within the bore of the nose end of shell[illegible] machine employs a special adapter su[illegible] a boring tool of the replaceable bit ty[illegible] curate alignment of the work is ins[illegible] round serrated grips. In addition, a work support or cradle is employed to [illegible] handling. A lead screw is used to [illegible] work to the boring tool

Load Ratio $L_1 = M/mp_1a^3$ ⟶ ⟵ Load Ratio $L_1 = 1/4 = mp_1a^3$

Below—Designed for resistance welding of heavy sections of special alloy steels, automatic control of current and operating cycle of Progressive welder is effected by the temperature at the weld. Similarly regulated as a part of the welding cycle is a heat treating or an annealing phase which effectively reduces errors due to the human element and compensates for line voltage variations



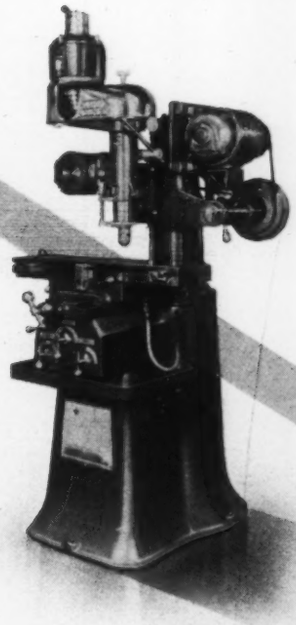


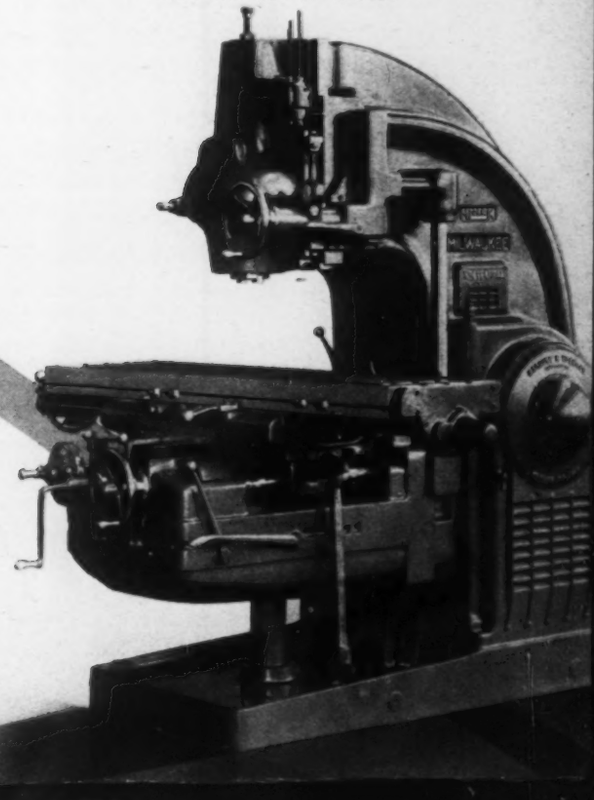
Above—Driven by V-belts and powered by a three-horsepower reversing motor, spindles of Hammond carbide tool grinder are oversize and bearings are protected by positive oil-water and labyrinth seal. Incorporated is a new and unique compound protractor tool gage which is entirely universal. In addition to sliding in table slot parallel with the wheel it also has cross slide for movement toward wheel

n Machines

ew mac... see Page 156)

Below—Increased range of operation and greater facility of control is obtained in Milwaukee vertical milling machine by means of hydraulically actuated starting levers located in duplicate both front and rear. Extreme rigidity, permitting work to close tolerances, is obtained by massive solid-back column, cross-mounted motor, center bearing spindle, large diameter overarms, and a carefully engineered distribution of metal





Above—Mounted on a single rigid turret capable of rotation through 360 degrees, Armor universal turret milling machine utilizes combination of a horizontal and vertical spindle. Smooth power for deep cuts is afforded by hydraulic drive of longitudinal table

MACHINE DESIGN *Editorial*

Speed Production Through Automaticity and Ease of Control!

TEN million more workers, it has been said, will be engaged in production for war at the end of 1942 than at the beginning of the year. Mobilization of the manpower of the country to accomplish this undoubtedly means that men—and women—who may never before have seen the inside of a machine shop will be operating lathes, drill presses and numerous other types of indirect war equipment.

Though the majority of these machines are already in use a huge quantity of new machines is being manufactured. Others are still in the development stage. It is in the design of the latter that consideration should be given, not only to speed and effectiveness in production, but also to simplicity and ease of control.

The more automatic the machines, the less the need for long courses of operator training. And the greater the ease of operation of nonautomatic equipment, the greater the day's output.

With the 60-hour or more workweek that may be adopted in the near future the need for simplicity, automaticity and ease of operation offers a challenge to designers second only to the vital requirements of reliability and speed.

Many designers have in the past concentrated their efforts on styling or "industrial design". To no better purpose could these men now put their ingenuity than toward the development of machines incorporating servo-mechanisms, electrically-operated controls, or other means of reducing fatigue and speeding war production.

Why No Name?

IN ORDER to co-operate to the fullest extent with the government censorship bureau, MACHINE DESIGN purposely eliminates certain information from its articles. Such deleted references usually cover the names and locations of companies producing war machinery, or in some instances the intimate details of special armament equipment.

It is felt that readers fully appreciate the necessity for this policy and that they also understand the reason for nonpublication at this time of articles on design that might be of "aid and comfort to the enemy." All contributions or other material appearing in the magazine which might, even in the remotest sense, come under such a classification, are published only with the full approval of the Office of Censorship in Washington.

L. E. Jerry

Design Data for Rubber Mountings

Part II

By Elmer Latshaw

J. G. Brill Co.

REFERENCE to Pages 173 and 174 of the April issue, prefacing the first of this two-part series, will be of considerable assistance in designing rubber shear mountings, using the following formulas. For convenience, the nomenclature for the variables appearing in the formulas is repeated here.

Nomenclature

A = Rubber bond area, square inches
D = Deflection, inches
E = PD = 2× work stored, inch pounds
e = Base of natural logarithmus
G = Shear modulus, pounds per square inch
H = Height, inches
H' = Height, inches
h = Height (variable) inches
k = Radius factor, pure number
m = Function of k, pure number
n = Function of k, pure number
P = Load, pounds
q = Shear stress, pounds per square inch
r = Radius, inches
R = Radius of torque, inches
t = Rubber thickness, inches
θ = Torsional deflection, degrees
V = Rubber volume, cubic inches
x = Variable radius, inches

(1) $H = k^2 H'$

(2) $r^2 H = \dfrac{PR}{2\pi q}$

(3) $m = \dfrac{DG}{Rq}$

(4) $t = (k-1)r$

(5) $q = \dfrac{DG}{Rm}$

(6) $D = \dfrac{PR^2 m}{ArG}$

(7) $P = \dfrac{Arq}{R}$

(8) $A = 2\pi rH$

(9) $V = Arn$

(10) $E = \dfrac{q^2 V}{G}\ \dfrac{m}{n}$

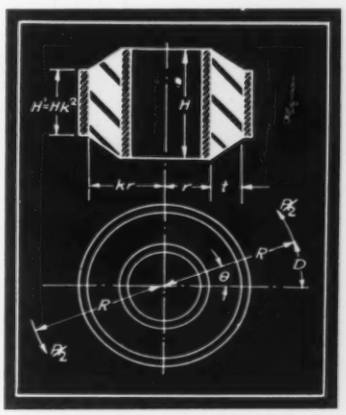
(11) $m = \dfrac{(k-1)^3}{2(k^3-1)^3}\left[(k^6-1)+4k(k+1)(k^3-1)+6k^2(k+1)^2 \log_e k\right]$

(12) $n = \dfrac{(k^3-1)(k+1)}{6k^2}$

(13) $\theta = \dfrac{180\,D}{\pi R}$

Fig. 6—Bond areas are proportioned to give equal shear stresses on both tubes. Since the edge of the rubber follows a straight line, rubber is stressed lower at intermediate radii

k-1	m	n	m/n
.0	.000	.000	1.00
.2	.179	.185	.97
.4	.318	.356	.89
.6	.422	.524	.81
.8	.499	.696	.72
1.0	.554	.875	.63
1.2	.595	1.061	.56
1.4	.623	1.261	.49
1.6	.643	1.472	.44
1.8	.656	1.691	.39
2.0	.666	1.926	.35



(1) $H' = H$

(2) $r^2H = \dfrac{PR}{2\pi q}$

(3) $m = \dfrac{DG}{Rq}$

(4) $t = (k-1)r$

(5) $q = \dfrac{DG}{Rm}$

(6) $D = \dfrac{PR^2m}{ArG}$

(7) $P = \dfrac{Arq}{R}$

(8) $A = 2\pi rH$

(9) $V = Arn$

(10) $E = \dfrac{q^2V}{G}\ \dfrac{m}{n}$

(11) $m = \dfrac{k^2-1}{2k^2}$

(12) $n = \dfrac{k^2-1}{2}$

(13) $\theta = \dfrac{180\ D}{\pi n}$

k-1	m	n	m/n
.0	.000	.00	1.00
.2	.153	.22	.69
.4	.245	.48	.51
.6	.304	.78	.39
.8	.346	1.12	.31
1.0	.375	1.50	.25
1.2	.396	1.92	.21
1.4	.413	2.38	.17
1.6	.426	2.88	.15
1.8	.436	3.42	.13
2.0	.444	4.00	.11

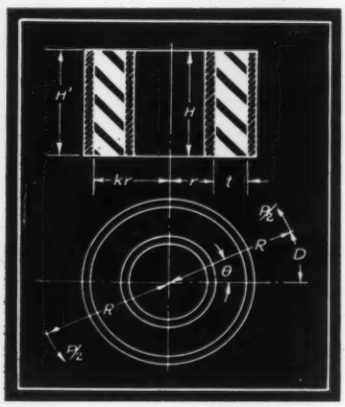


Fig. 7—Since the unit is of uniform height, the bond area on the inside tube is stressed to the highest value. The shear stress diminishes rapidly toward the outer tube giving low efficiency

(2) $r^3 = \dfrac{PR}{\pi q m}$

(4) $t = \dfrac{DGr}{qR}$

(5) $q = \dfrac{DGr}{tR}$

(6) $D = \dfrac{PR^2t}{\pi r^4 G m}$

(7) $P = \dfrac{\pi r^3 q m}{R}$

(8) $A = \pi r^2(1-k^2)$

(9) $V = \pi r^2 t m$

(10) $E = \dfrac{q^2V}{G}$

(11) $m = \dfrac{2(1-k^3)}{3}$

(13) $\theta = \dfrac{180\ D}{\pi R}$

k	m
.0	.667
.1	.666
.2	.661
.3	.649
.4	.624
.5	.583
.6	.523
.7	.438
.8	.325
.9	.181
1.0	.000

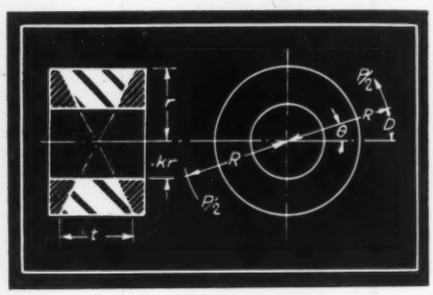


Fig. 8—Making the rubber thickness directly proportional to the radius gives uniform shear stress throughout. This is the ideal type of torsional disk spring

(2) $r^3 = \dfrac{PR}{\pi q m}$

(4) $t = \dfrac{DGr}{qR}$

(5) $q = \dfrac{DGr}{tR}$

(6) $D = \dfrac{PR^2t}{\pi r^4 G m}$

(7) $P = \dfrac{\pi r^3 q m}{R}$

(8) $A = \pi r^2 n$

(9) $V = \pi r^2 n t$

(10) $E = \dfrac{q^2V}{G}\ \dfrac{m}{n}$

(11) $m = \dfrac{(1-k^4)}{2}$

(12) $n = (1-k^2)$

(13) $\theta = \dfrac{180D}{\pi R}$

k	m	n	m/n
.0	.500	1.00	.50
.1	.500	.99	.50
.2	.499	.96	.52
.3	.496	.91	.54
.4	.487	.84	.58
.5	.469	.75	.62
.6	.435	.64	.68
.7	.380	.51	.74
.8	.295	.36	.82
.9	.172	.19	.90
1.0	.000	.00	1.00

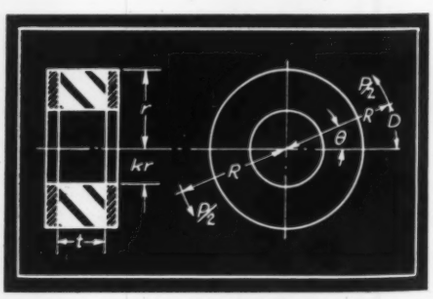


Fig. 9—Since the rubber thickness is uniform for any radii, the shear stresses will vary, increasing toward the outside. Variable stress indicates reduced efficiency

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Applications

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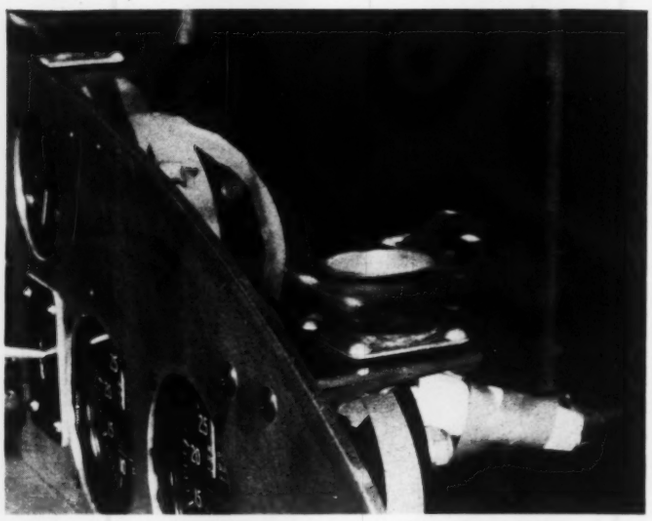
Protected from Vibration

ISOLATION of engine and aerodynamic vibrations from delicate airplane instruments is essential to their accurate operation. In the illustrated set-up, six Lord shear-type rubber mountings are used; three at the top and three at the bottom of the instrument panel. Blurred appearance of the mounting bracket is due to its vibration at the rate of 2400 cycles per minute. Sharpness of the photograph of the instrument panel is indicative of how effectively the mountings prevent the transmission of vibration. Use of mountings in series doubles the axial softness over the rating of the individual units and gives large load capacity without loss of extreme sensitivity.

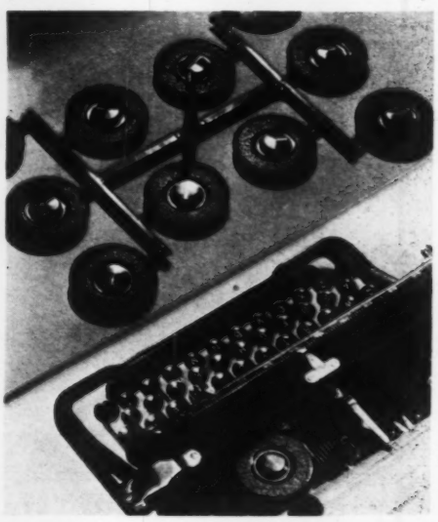


Stainless-Clad Replaces Brass

IN FOOD handling machines, corrosion which might lead to contamination must be prevented. The conveyor chain of the Cherry-Burrell machine was formerly made of sheet brass. When brass became a "critical" material the company was forced to find a suitable substitute in order to continue producing this machine so vital to the nation's health. Stainless-clad steel was found to possess the nontarnishing and corrosion-resisting properties of the brass sheets formerly used. By using stainless-clad steel instead of solid stainless, about 80 per cent of the high alloy material has been conserved for the war effort.

Molded with Integral Finish

TYPEWRITER ribbon spool covers are injection molded of Tenite, ten at a time, as illustrated in the upper part of the picture. They come from the mold with the same bright wrinkle finish as the metal parts of the typewriter and are made ready for assembly by simply trimming off the gate scrap. Because of the resilience of this plastic, two projecting prongs molded on the underside are all that is necessary to hold the covers securely in place.



Conversion TO WAR PRODUCTION CALLS FOR MORE INFORMATION ABOUT ALLOYS...

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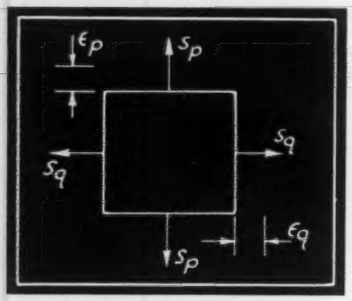

Fig. 5 — Principal stresses on a unit volume afford basis for interpreting strain data in terms of stress

(*Continued from Page 67*)

still within the permissible working range of the gage.

Where a varying stress distribution is known to exist, and it is desired to determine that distribution, a number of individual gages located at critical points may be used. From these data a plot of the stress distribution across the section may be made, and bending direct stresses subsequently isolated.

One such case is illustrated by the arrangement used to determine the stress distribution across the unsymmetrical *I* section of an extremely large, forged fitting, part of which is shown by *Fig.* 2. Distribution of pickups is shown, together with a section of the record taken during a landing. For convenience these circuits usually are so arranged that tensile stresses are indicated by an upward swing of the trace, and vice versa for compression. The vertical lines are time lines, 1/10 of a second time interval being indicated by each space. The redistribution of bending stress due to beam curvature is another field that has been investigated by a similar installation.

When bending stresses are the sole concern it is possible to use two gages on opposite sides of a bending member, interconnected in a single circuit so that the total stress differential (a combination of the tenson on one side plus the compression on the other) is indicated. Such applications are particularly accurate because the nature of the circuit is such that the two gages are used on opposite legs of the bridge. No extra dummy gages are necessary and automatically perfect temperature compensation is obtained. Wherever the nature of the problem is such that the determination of a total bending differential stress is satisfactory for the purpose, such an installation is ideal.

Frequent need for dummy gages referred to in the foregoing arises from the fact that in the bridge circuit it is essential to balance the resistance of the gage unit against another identical resistance. Easiest and most satisfactory way to attain this condition is to use another gage—a dummy gage. Most satisfactory temperature compensation is achieved if the dummy is mounted on the same kind of metal as that on which the stresses are to be invested. Metal on which the dummies are mounted must, of course, be unstressed. Hence a separate sheet is advisable, as illustrated on the right of *Fig.* 4.

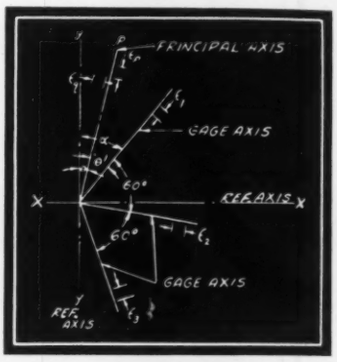

Fig. 7 — Delta arrangement of gages provides data for obtaining magnitude and direction of principal stresses

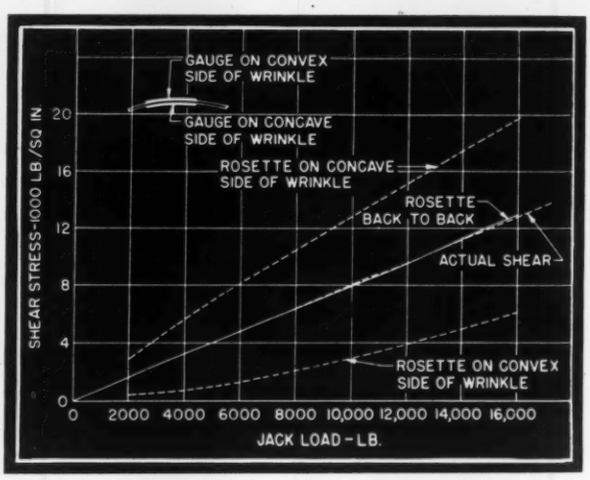

Fig. 8—Wide disparity of data from single gages on one surface emphasizes necessity of using them "back-to-back" in pairs

In the general case, with the direction and magnitude of the principal stresses unknown, it is always possible to determine the complete state of stress on a surface if a sufficient number of strains directionally disposed at sufficiently large angles to each other are known.

Literature covering the mathematics of the determination of the state of stress from such data is fairly complete, having been developed originally for use with mechanical gages*. Of all the available methods, the use of three gages, each forming an angle of 60 degrees with the other, in the shape of a delta, as shown by *Fig.* 4, lends itself most

* "A semigraphical method for analyzing strains measured on three or four gage lines intersecting at 45 degrees," *Technical Note* 709, National Advisory Committee on Aeronautics.
"Strain Star Formulas"—Dr. W. B. Klemperer, *Douglas* S. M. 3126.
"The Tensor Gage," *Journal of Aeronautical Sciences,* July, 1940.
"The Determination of Stresses from Strains on Three Intersecting Gage Lines," U. S. Department of Commerce, Bureau of Standards *Research Paper* No. 559.
"Circles of Strain"—J. Wise, *Journal of Aeronautical Sciences,* August, 1940.

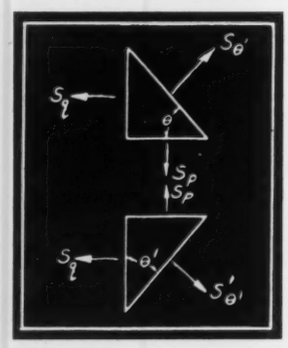

Fig. 6—Developed from Fig. 4, sketch illustrates method of determining stress on any plane inclined at an angle to the selected element

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easily to rapid mathematical reduction. The result sought is the determination of the direction and magnitude of the principal stresses from which any desired components, such as the shearing stresses, may be established. A sketchy development of the mathematics involved follows.

An element, oriented in such a manner that only principal stresses exist, is considered and illustrated by *Fig.* 5. The strain in each direction is

$$\epsilon_p = \frac{S_p}{E} - \mu\frac{S_q}{E}$$

$$\epsilon_q = \frac{S_q}{E} - \mu\frac{S_p}{E}$$

where μ = Poisson's ratio.

Solving the strain equations for stresses in the direction of the strains, the following fundamental equations are obtained:

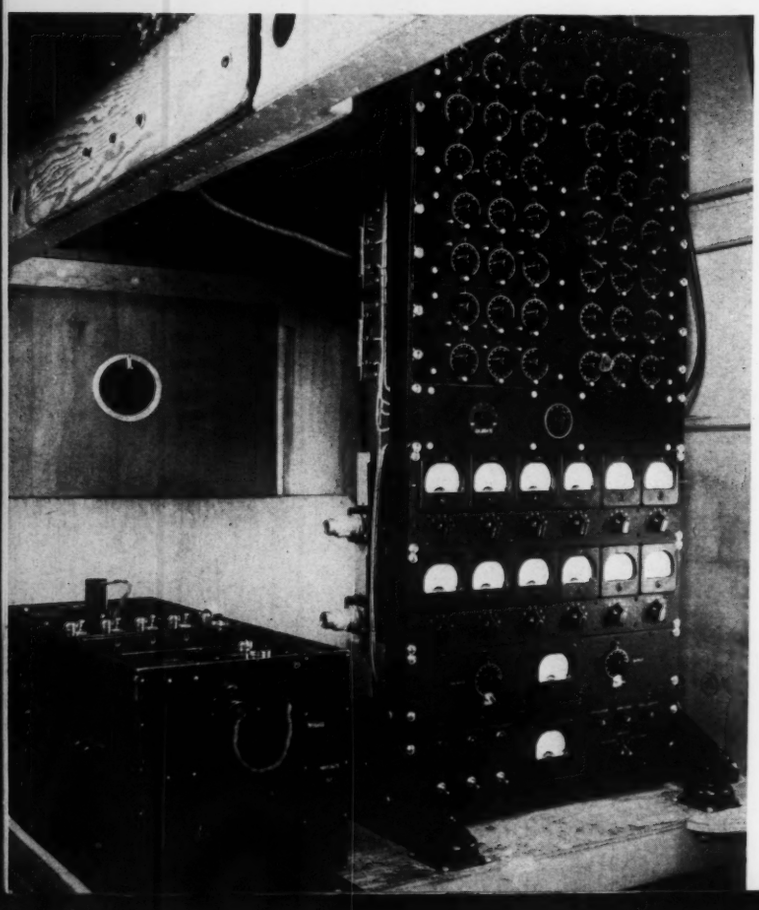
$$S_p = \frac{E}{1-\mu^2}(\epsilon_p + \mu\epsilon_q)$$

$$S_q = \frac{E}{1-\mu^2}(\epsilon_q + \mu\epsilon_p)$$

Therefore, if the strains are known in the direction of the principal stresses, a solution for the principal stresses can be obtained.

In most cases, however, the direction of the principal stresses is not known. The use of three known strains in a direction 60 degrees to each other will give all of the principal stresses. The direction in relation to any reference line of these stresses may also be determined.

Fig. 9—Instruments and selector switches afford centralized control of tests on airplane under simulated flight conditions



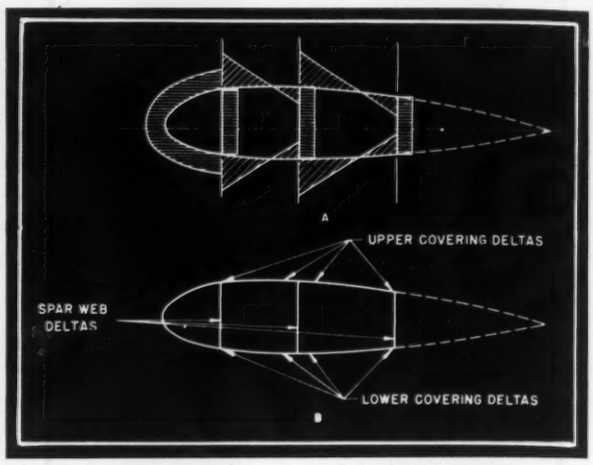


Fig. 10—Stress distribution chart of wing section is obtained by location of strain gages as illustrated in lower sketch

Stress in any plane at an angle θ', shown in *Fig.* 6, is

$$S_{\theta'} = S_p \cos^2\theta' + S_q \sin^2\theta'$$

$$S'_{\theta'} = S_p \sin^2\theta' + S_q \cos^2\theta'$$

By substituting proper strain values in these equations the strain is

$$\epsilon_{\theta'} = \left(\frac{\epsilon_p + \epsilon_q}{2}\right) + \left(\frac{\epsilon_p - \epsilon_q}{2}\right)\cos 2\theta'$$

If the terms $(\epsilon_p + \epsilon_q)/2$ and $(\epsilon_p - \epsilon_q)/2$ are defined and ϵ and Δ respectively, the strain in any direction in terms of the principal strain values is

$$\epsilon_{\theta'} = \epsilon + \Delta\cos 2\theta'$$

As shown by *Fig.* 7, the following equations result

$$\epsilon_1 = \epsilon + \Delta\cos 2\theta'$$

$$\epsilon_2 = \epsilon + \Delta\cos 2(\theta' + \pi/3)$$

$$\epsilon_3 = \epsilon + \Delta\cos 2(\theta' + 2\pi/3)$$

The angle α is shown from the installation of the gages. A solution of the foregoing equations yields

$$\epsilon = \frac{\epsilon_1 + \epsilon_2 + \epsilon_3}{3}$$

$$\Delta = \frac{\epsilon_1 - \epsilon}{\cos 2\theta'}$$

$$\tan 2\theta' = \frac{\sqrt{3}}{1 + 2\left(\frac{\epsilon_1 - \epsilon_2}{\epsilon_2 - \epsilon_3}\right)}$$

Since ϵ and Δ are already defined, a complete solution of the principal strains may be obtained.

$$\epsilon_p = \epsilon + \Delta, \quad \epsilon_q = \epsilon - \Delta \quad \text{and} \quad \theta = \alpha - \theta'$$

Knowing the principal strains, the principal stresses may be calculated as previously mentioned. The maximum shear stress follows from a known relationship

$$T_{max} = \frac{S_p - S_q}{2}$$

WHEN PROMPT DELIVERY COUNTS SO MUCH

NOW, when your products are so urgently needed, you can profit by the ready availability of the Torrington Needle Bearing. As a result of Torrington's expansion program, Needle Bearings in standard sizes and types can be *promptly delivered on all priority orders!*

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IT CONSERVES OTHER MATERIALS on which you may be encountering delivery problems. Because of the Needle Bearing's small outside diameter, you can reduce the size of your housings, and hence the amount of material required.

IT ELIMINATES EXTRA PARTS AND ASSEMBLY STEPS. No retaining rings, washers, or end plates are needed to hold the bearing in place—and in most applications, no special lubricating equipment need be provided.

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Established 1866
TORRINGTON, CONN. U. S. A.
Makers of Needle and Ball Bearings
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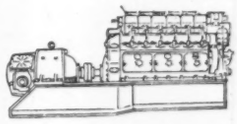
TORRINGTON NEEDLE BEARING

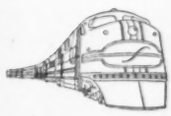
LONG SERVICE LIFE



High load capacity and efficient lubrication of the Torrington Needle Bearing result in long service life on the valve rocker arms of Model 36 Diesels built by Fairbanks, Morse & Co. Bearings reduce the need of replacements and of other service attention.

FAIRBANKS, MORSE

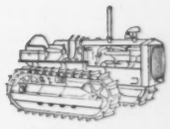
HIGH EFFICIENCY



Efficiency and dependability of operation are essential in railroad auxiliary equipment. Safety Car Heating & Lighting Co., Inc., obtains these advantages by using Torrington Needle Bearings on automatic control valves of its Carrier-Safety air conditioning systems.

SAFETY CAR

EFFECTIVE LUBRICATION



Because the Needle Bearing's outer race forms a reservoir holding ample quantities of lubricant, the need for service attention is reduced to a minimum. Caterpillar Tractor Co. profits by this feature in its famous line of "Caterpillar" Diesel Tractors.

CATERPILLAR TRACTOR

How this Stainless Tubing BOOSTS War Production and CONSERVES Vital Metal . . .

In making parts for planes, tanks, machine guns, ships, etc. - -

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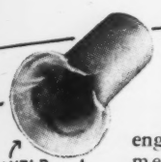
is possible with Carpenter Welded Stainless Tubing. Its ductility and uniform structure mean *easier* bending, cutting and welding. Expanding and flanging can be done *faster* with fewer rejects. As tubing shapes are natural design units, parts can often be finish formed by merely swaging, flanging, tapering, etc. — with a *minimum of machining.*

METALS CONSERVED

by using this tubing can be used to make *more* war machines and processing equipment. Scrap losses are minimized as this tubing is made from strip. Uniform wall thickness permits using lighter gauge tube. And *less machining* in your plant means *time saved* and *metals conserved.*

PHYSICALLY,

Carpenter Welded Stainless Tubing offers these advantages to designers, fabricators and users: a variety of Stainless types to meet specific performance requirements; high *resistance to heat and corrosion;* meets *Army* and *Navy* specifications; each length 100% *hydrostatically tested.*



STRENGTH!

This piece of tubing (from a regular production run) was flare tested to determine the strength of the weld. When the break occurred, it was AWAY FROM the weld. This tubing can often carry loads formerly supported by solid bars or heavier-walled tubing.

IF you are an engineer doing experimental or research work, ask to receive our "Quick Facts" bulletins. They provide users of Stainless Tubing with tips to help speed production and make each length of tubing work harder. A note on your company letterhead will bring you "Quick Facts" bulletins.

THE CARPENTER STEEL COMPANY

Welded Alloy Tube Division, Kenilworth, N. J.

Carpenter
WELDED
STAINLESS TUBING

Use of such strain deltas has become standard practice for determining stresses in thin sheet. A typical installation on a spar web is shown by *Fig.* 4. For the general case in aircraft work, such sheets will be operating in the wave state. Additional bending stresses imposed by the buckling of the sheet are surprisingly large. The effect of such large bending stresses is to render the indications of a delta, attached to one side of the sheet only, very unreliable so far as determining average conditions is concerned. For that reason, unless it is known that buckling will not occur, deltas are invariably installed with gages back to back. Each leg of the delta is then connected with its counterpart on the opposite side of the sheet to read an average stress which automatically cancels out the additional bending stresses due to wave formation. *Fig.* 8, which is based on tests conducted to investigate these points, illustrates them well. Wide divergence in shear stress indicated by the surface stresses on one side of the sheet only, by comparison either with the delta on the other side or with the known overall shear, is startling.

Gages Separated by Half Wave Length

Cases exist in which such an arrangement is not feasible. For instance, one side of the sheet may form the inner wall of an integral gas tank. It is possible in such a situation to indulge in the harmless trickery of installing two deltas on the same side of the sheet, oriented so that each leg is parallel to its counterpart, spaced one-half wave length apart and connected as before, to read an average strain. The wave length for a particular stress can be calculated ahead of time with reasonable accuracy and tests have indicated that the accuracy is little affected by slight errors in the spacing. Some gain in accuracy is achieved by installing the three gages forming the delta in as small a pattern as possible. A point would be ideal but unfortunately is not practicable.

Herein reference is made particularly to static tests of complete airplanes, or to tests made during flight. In such cases the wiring between the gage units and the associated apparatus becomes a considerable undertaking. The gage units themselves are cheap but it is necessary to use as few channels as possible to hold the installation wiring problems to a reasonable scale. Furthermore, in flight testing, the number of channels available simultaneously is sharply restricted. None may be wasted on extraneous information. In fact, the larger problems under investigation often must be broken down into phases which can be handled one at a time by the available equipment. Means must then be provided to switch from one phase to another when, as is usually the case, more than one phase must be covered during a single flight.

Fig. 9 is a photograph of the installation of the amplification and recording apparatus set-up during a static test of a complete airplane. In this case cables and all the wiring from the gages installed all over the airplane have been brought to a stand

ZINC IN WAR

"KEEP" [illegible]thy"

It is rather ironic that zinc is used in the brass for shells that wound men—and in pharmaceuticals that heal them. Such is the futility of wars, yet such is the widespread importance of zinc when wars are thrust upon us. The use of zinc oxide in the preparation of adhesive tape, ointments and other medicinal products is one which carries an unquestioned preference rating. Pharmaceutical (U.S.P.) zinc oxide is the purest type of zinc oxide known and it is characterized by several outstanding qualities. It is protective, mildly astringent and adhesive. The exceptional fineness and whiteness of this zinc oxide makes it especially suitable in ointments, dusting powders and adhesive tape.

While most of the war uses, shown in the index of this book, involve larger tonnages of zinc than U.S.P. zinc oxide, few are more important from a utility standpoint. The needs of the Medical Departments of our armed forces are just another reason why civilian users of zinc may not be able to obtain all of the metal or pigment they would like to use.

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MANUFACTURERS OF THE FAMOUS HORSE HEAD ZINC PRODUCTS

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New Jersey zinc

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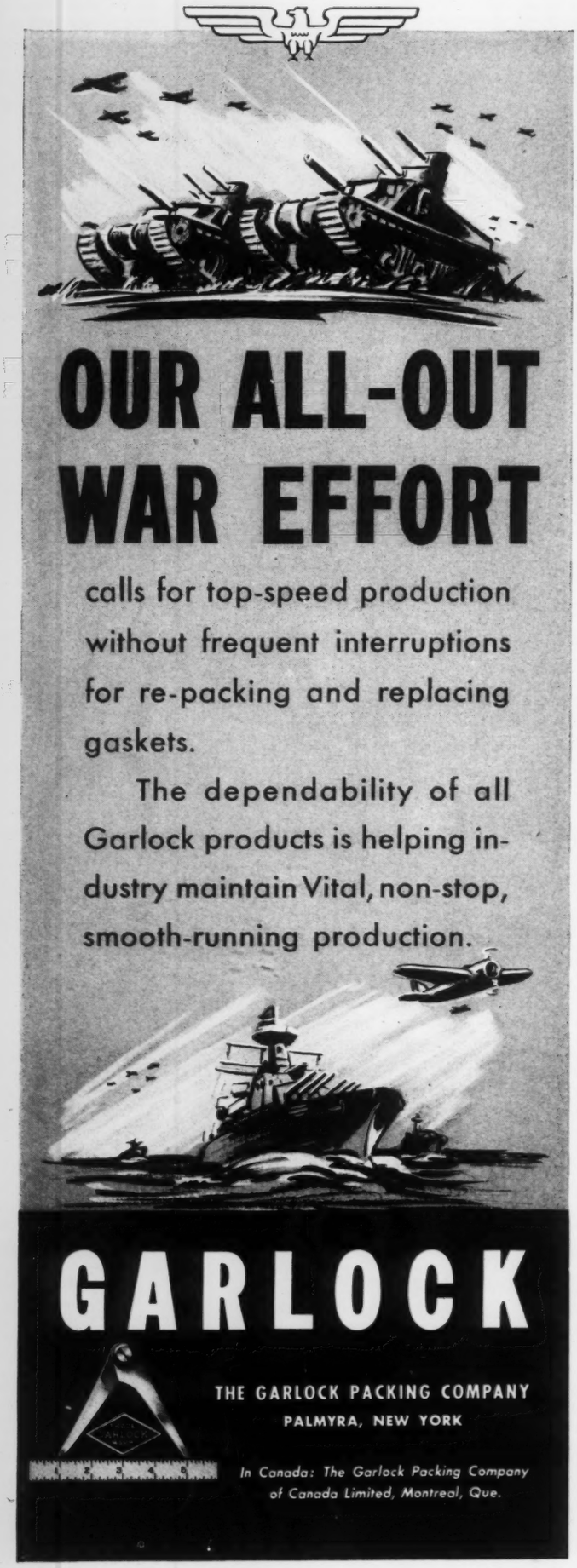
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GARLOCK
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conveniently set up outside of the airplane. The unit to the left is a six-channel amplifier with its associated meters. The center instrument is an electronic potentiometer being used to record indications from some 300 strain gage installations. This instrument incorporates an electronic amplifier and a high-speed self-balancing bridge system. A switch panel is shown to the right which permits selection of any one of the 300 channels.

As an example, the familiar and still difficult problem of the distribution of direct and torsional shear stresses in a multispar stressed skin wing is represented diagrammatically by *Fig.* 10*A*. Stresses shown will be the combination of direct and torsional shears plotted vertically from the contour of the wing section as a base. Their value largely determines the skin thicknesses, the spar web thicknesses, something of the stiffener arrangements involved, and the rivet patterns for seams in the wing covering. Therefore, the accurate evaluation of these intensities is important. The methods of calculating such shear intensities are somewhat involved. A substantiation of their accuracy is, of course, desirable.

Calculations and Test Data Disagree

From what has already been said it is obvious that, at a particular cross section of the wing, strain deltas could be installed at each point of maximum shear stress intensity, both on the wing covering and the spar webs. Their arrangement is indicated by *Fig.* 10*B*. For a wing such as the one sketched the installation would involve 12 deltas, or 36 channels.

In calculating such a stress distribution, the usual procedure is to distribute the direct shear among the spars in proportion to the spar web area. Such a procedure is based on the fact that the twisting deflections of a monocoque wing are small. The method of calculating the shear pattern illustrated in *Fig.* 9*A* involves the determination of the position of the elastic axis defined as the locus of points about which no angular deflection would occur were load applied at that point.

So far, agreement between mathematical methods of calculating the elastic axis position and test determination has not been satisfactory. Since the axis cannot be accurately located during the design stage, common practice has been to define conservatively a range of chord positions within which the axis should lie and to design the wing structure for the loads implied by the extremities of the assumed range. This involves a doubling of much analysis work and the inclusion of more structural weight than is actually necessary were the position of the elastic axis accurately known.

Starting from the strain gage data derived from an installation as indicated by *Fig.* 10*B*, it is possible to work in the opposite direction, separate out the various contributory shear stresses, and arrive at the true shear center of the elastic axis. That is being done and a wider experience with it will ultimately lead to reduced weight and analysis time.

So far the discussion has been devoted to the

ACCURACY IN ACTION

Ohio Seamless Tubing gears up routine to meet vital new responsibilities . . . Performance under fire . . . to that end steel tubing can make a most vital contribution to the production of firearms. It accounts for the variety of applications to firearms manufacture for which Ohio Seamless Tubing is now being used. Nor is accuracy the whole story. The rest is speed in manufacture—more guns, faster! That means geared-up routine to help meet ever-increasing demands of top-rating priorities. Precise machining to close tolerances, uniform workability, accurate sizes and gauges, smooth surfaces inside and out—all these qualities make for high speed production. So when the Army and Navy specify that tubing must be straight, sound, clean, and free from pits, scores, and other surface imperfections of any nature, Ohio Seamless Tubing can fill those requirements at a far greater pace than ever before. All this adds up to a vast new experience in the manufacture of Ohio Seamless Tubing to help you meet post-war reconstruction requirements.

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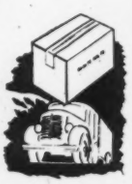

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favorable side of the picture. In order to restore a proper sense of proportion, however, it will be necessary to discuss some of the difficulties that are involved. There are of course technical difficulties. Low stresses may be indicated if there exists a lag due to imperfect cementing of the gage to the surface in question. Yield of the wire of the gage itself at higher stresses may cause difficulties. Moreover, troubles common to any involved electrical circuit may be encountered, and so on.

Aside from technical difficulties with the equipment itself, there are endless human problems involved in any large scale application of this technique. One definitely cannot expect the mere thoughtless application of huge numbers of gages to lead automatically to wonderful results.

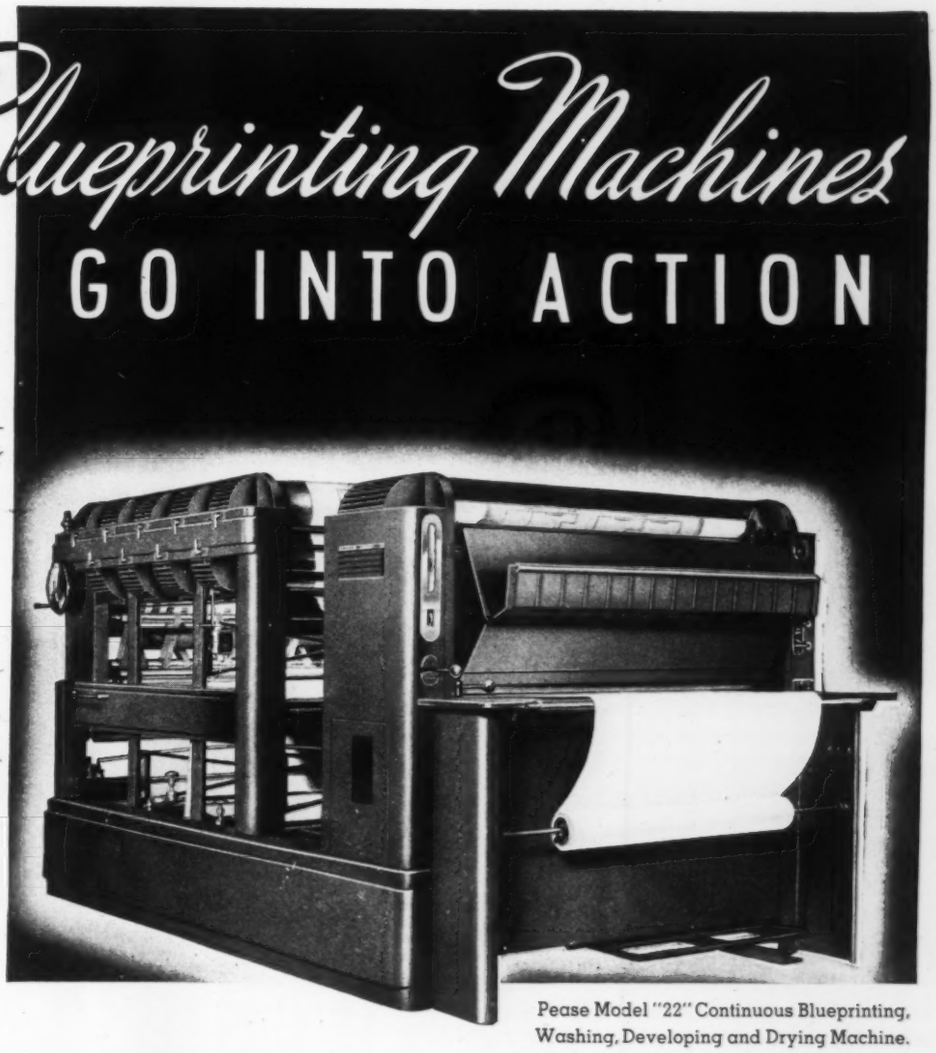
Preliminary Trials Necessary

Such difficulties as do occur may not be so serious in laboratory work because tests can be repeated there with reasonable ease, but in large scale static test work and in flight test work an error that invalidates a recording of events may spoil an opportunity to secure data that will never occur again. In flight test work, in particular in allotting flight time to this phase of the work, it is wise to anticipate repetition of each run several times until the entire installation is known to be in perfect order. Such preliminary trials will usually be necessary before a satisfactory record is obtained.

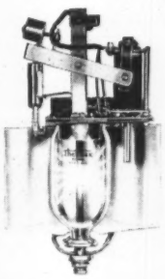
Even apparently satisfactory results, so far as the equipment is concerned, have to be used with a great deal of understanding. We know from sad experience that we have to be smarter than the gages in every application of them. They will give false answers and misleading information to anyone who will believe too easily. It is necessary to have sufficient understanding to recognize misinformation, to analyze the nature of it, to trace the trouble to its source, and to repeat that process until satisfactory results are being achieved. It is heartbreaking, after days and weeks of work and planning, to reduce the results contained in a record that appears satisfactory only to discover that some vital part of the installation is not working as intended. Such occurrences always seem to strike at the one most vital point. I do not know whom I quote, but whoever it was that first referred to the "innate perversity of inanimate objects" could well have been discussing his experience with such equipment.

This paper has purposely refrained from too great detail or actual figures which would apply only to specific cases. It has been primarily concerned with conveying the idea that there are techniques and equipment available, the application of which, though difficult, gives an insight into the problems of structural behavior which has never been possible before. Such an insight is particularly important in aircraft work with thin metal structures, the whole theory of which is still in the development stage. It is hoped that the end result is a better and a simpler structure, hence an airplane that is easier to build and more efficient when put to use.

Pease Blueprinting Machines GO INTO ACTION



Pease Model "22" Continuous Blueprinting, Washing, Developing and Drying Machine.



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Pease High Power "Actinic" Enclosed Arc Lamp features an exclusive shunt circuit, which permits operation at 10, 15, and 20 amperages at will.

OTHER OUTSTANDING FEATURES OF MODEL "22"

Sliding "Vacuum-like" Contact • Horizontal Water Wash • Quick Change Chemical Applicator System • Thermostatically Controlled Drying Drums, either gas or electric.

MORE and faster Blueprints is the order of the day in the nation's defense plants from coast to coast.

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Government Departments, Commercial Blueprinters and Industrial Organizations with expanding requirements and rapidly maturing plans rely on Pease Blueprinting Equipment to speed vital production.

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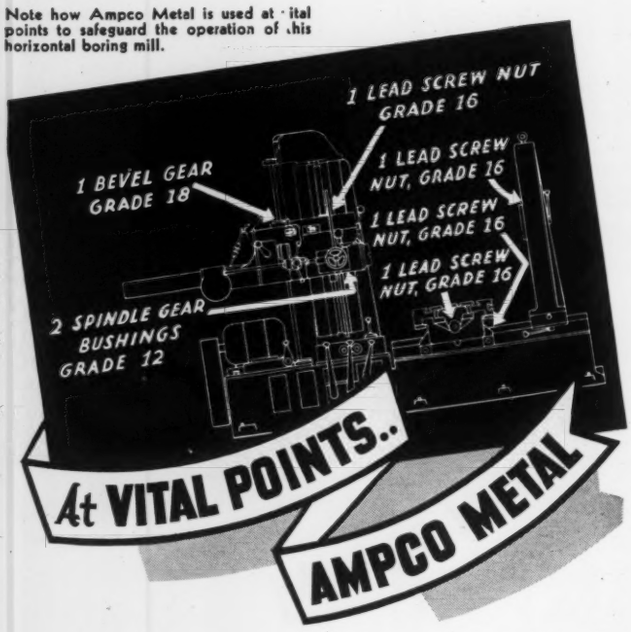
Blueprinting Machines A TYPE AND SIZE FOR EVERY REQUIREMENT INCLUDING DIRECT PROCESS PRINTING

Note how Ampco Metal is used at vital points to safeguard the operation of this horizontal boring mill.


1 LEAD SCREW NUT GRADE 16
1 BEVEL GEAR GRADE 18
1 LEAD SCREW NUT, GRADE 16
1 LEAD SCREW NUT, GRADE 16
1 LEAD SCREW NUT, GRADE 16
2 SPINDLE GEAR BUSHINGS GRADE 12
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3 to 5 Times More Service Life

Customer satisfaction — continuous production — depend upon the smooth functioning of all parts of the machine. Vital parts subject to friction and wear must give long life—must stand up and "take it" under severe operating conditions.

Designing engineers and production executives who specify materials are incorporating parts of Ampco Metal into their equipment at strategic points—for this alloy of the aluminum bronze class has the strength, hardness, and wearability so necessary for grueling service.

Ampco Metal is made in six grades with a range of hardness. Physical properties are uniformly high. It is essentially a bronze for the tough jobs where other metals fail. Usually it gives from three to five times more service than ordinary bronzes.

AMPCO LITERATURE Available

AMPCO METAL, catalog 22
Ampcoloy — Industrial Bronzes Catalog
Ampco — Trade Coated Aluminum Bronze Welding Rod
Ampco Metal in Machine Tools
Ampco Metal in Bushings and Bearings
Ampco Metal in Dies
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Ask for Literature

The panel to the left contains a list of literature available describing Ampco Metal as used in varied applications. Ask for those bulletins that meet your needs.

AMPCO METAL, INC.
Dept. MD-5
Milwaukee, Wisconsin

Carbon Offers Solution to Material Problems

(*Concluded from Page* 65)

ations are preformed to provide finished dimensions.

Thus in heavy or irregular sections variations in pressing pressure throughout the cross section of the piece as well as inevitable temperature gradients existing in certain stages of the baking operation may contribute to a uniformity problem across the section of a part. This condition can be to a large extent controlled by the carbon manufacturer based upon his long experience in the art. For these reasons the compounds in a given part should be dictated largely by the manufacturer.

As far as design criteria are concerned any object which can be die cast or plastic molded can be molded of carbon. An example of design development is provided by the gasoline meter valve previously discussed and illustrated in *Fig.* 2. The change from the original cast-iron valve to the aluminum die-cast type necessitated certain design changes, principally increased size and shape of the driveshaft splines which enter at the base of the valve. The driven fork which fits into blind holes in the top of the valve and actuates the computing gears was also slightly altered. The original cast-iron valve employed a slot and this shaping together with the fork used was undesirable in both the aluminum die casting and the carbon valve. As noted from the illustration, the carbon design maintained essentially the same shape as the die casting. The final carbon valve weighted one half as much as the cast-iron and slightly less than aluminum.

Molded to Close Tolerances

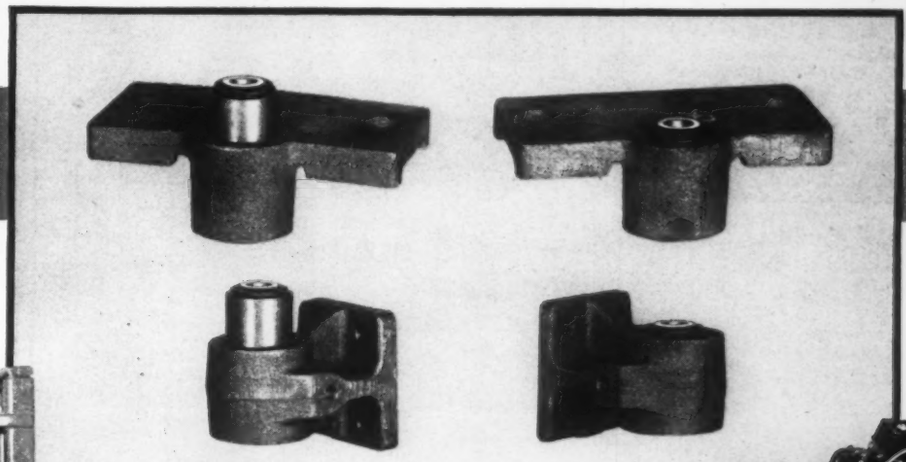
Some carbon compounds can be molded to within .001-inch total tolerance; closer dimensional limitations necessitate special finishing operations such as grinding, polishing, and superfinishing. The latter operation when applied to the noses of shaft seals and rotating joints affords perfect sealing even while the joints are stationary.

Size limitations depend to an extent upon the grade selected since the molding pressure for the most dense composition requires pressing pressures up to 18 tons per square inch. The diameter of parts ordinarily is held to 15 inches with thicknesses not exceeding this dimension.

Metal fittings for reinforcing or operation may be either molded in or applied after the finished piece is taken from the die. These points should be considered by the designer. Self-tapping screws and similar fastenings are used satisfactorily for attachment to co-operating machine elements. In developing the finished design for a carbon part it is desirable from the standpoint of economy that finished-machining operations be held to a minimum. While most grades are readily machinable with tungsten carbide tips or diamond tools the majority of machine work is done by grinding.

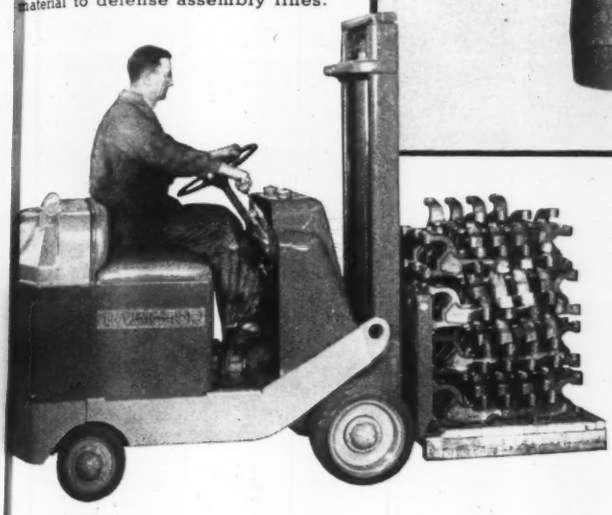
HOW LORD BONDED RUBBER VERTICAL SNUBBING MOUNTINGS

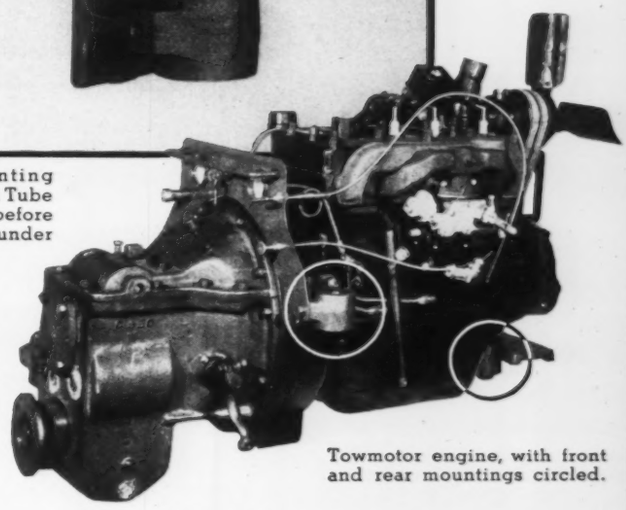
❶ Protect the power plant from shock and
❷ Isolate engine vibration on Towmotor industrial trucks



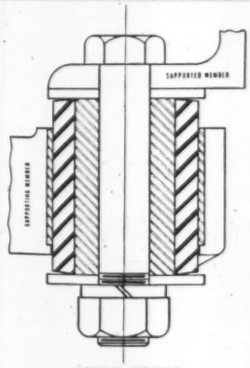
Front and rear mounting brackets showing Lord Tube Form V. S. Mountings before and after assembling under medium press fit.

Towmotor Industrial Trucks are an important factor in speeding flow of material to defense assembly lines.





Towmotor engine, with front and rear mountings circled.



TUBE FORM
VERTICAL SNUBBING (V.S.)

THESE husky little industrial trucks take a terrific beating as they carry their heavy loads over uneven factory floors. To cushion operating shocks and isolate engine vibration, Towmotor flexibly suspends its power plant on three Lord Shear Type Vertical Snubbing Mountings. The above photograph shows how these compact units are easily installed by pressing into sockets.

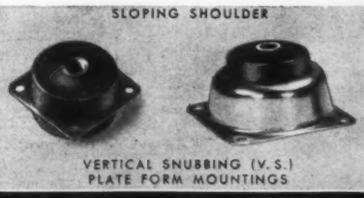
These mountings effectively prevent the engine vibration from reaching the chassis of the motor through free operation in shear. For example, at an engine speed of 1500 r.p.m. and mounting deflection of 3/32", 81% of the disturbing vibration would be isolated. When shock loads, caused by starting, stopping, bumping, or passing over rough floors, are encountered, rubber snubbing shoulders of the mountings cushion the shock impact and the mountings accommodate twisting action in the chassis without setting-up strain in the engine members.

Standard Lord Mountings such as used on this Towmotor installation are built in several sizes for supporting loads up to 1150 pounds each. For lighter loads, Lord V. S. Mountings are made in Plate Form. A new bulletin has been published describing Lord Vertical Snubbing Mountings in detail. Write for your copy.

LORD MANUFACTURING COMPANY . . . ERIE, PA.

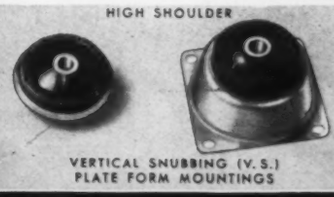
245 E. OLIVE AVE., BURBANK, CAL. 280 MADISON AVE., NEW YORK 520 N. MICHIGAN AVE., CHICAGO

CAL SNUBBING (V. S.)
E FORM MOUNTING



VERTICAL SNUBBING (V. S.)
PLATE FORM MOUNTINGS

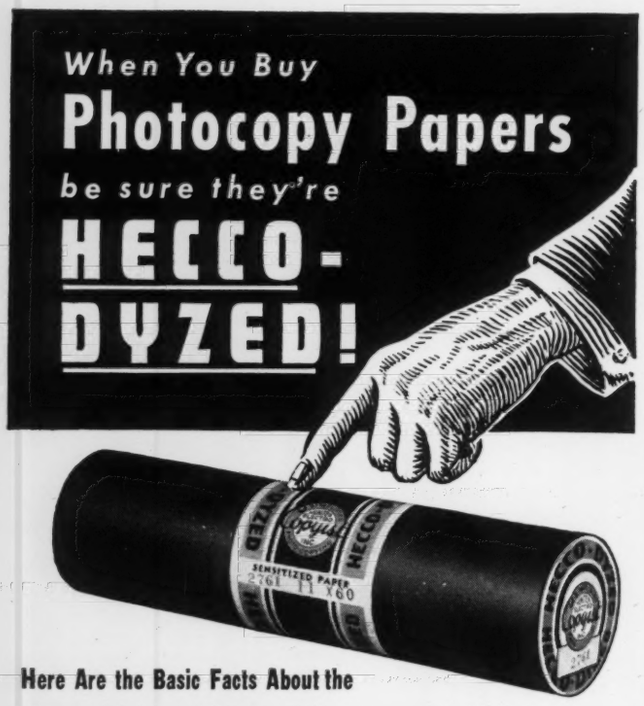
LORD
BONDED RUBBER
SHEAR TYPE
VIBRATION
MOUNTINGS



VERTICAL SNUBBING (V. S.)
PLATE FORM MOUNTINGS

VERTICAL SNUBBING (V. S.)
TUBE FORM MOUNTING

IT TAKES RUBBER IN SHEAR TO ABSORB VIBRATION



Here Are the Basic Facts About the Revolutionary New Hecco-Dyzed Process and What It Means to Everyone Doing Contact Photocopy Work—

No more half way, unsatisfactory, washed-out-looking prints. With Hunter Original Formula Papers—made by Hunter's exclusive Hecco-Dyzed Process—you can now be sure of all the perfection and sharpness of reproduction that your copying machine is capable of giving!

In the Hecco-Dyzed Process, a secret-formula dye is added to the sensitized emulsion. This revolutionary new dye controls the light reactions exactly to photocopy needs. Users say Hecco-Dyzing is the greatest single advance ever made in the science of photocopying!

The Difference Shows in Better Results

With Hunter Original Formula Papers, you'll get prints that are sharper and clearer—prints with colors accurately shown in shades of gray—prints that register accurately graduations of tone—prints with pure whites and completely opaque blacks—prints that develop perfectly even when made by inexperienced operators.

TRY Hunter Original Formula Papers FREE! Liberal samples will be sent you on request. See your local Hunter distributor or write us direct—*today*.

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A life-saver for jammed up Engineering Departments! Copies blueprints, drawings, specifications, priority extensions, etc.—at low cost—in a matter of seconds. Makes photocopy tracings on linen direct from pencil originals—transparent negatives on vellum—clear shop prints on durable paper. No proofreading necessary. Gets work into shop days faster—slashes drafting cost. Investigate. Write for free new folder.

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Professional Viewpoints

" . . . who invented airplane control?"

To the Editor:

The article entitled "Invention, War Inspires—Law Protects," by George V. Woodling in your February issue contains in *Fig.* 1, the words "Original patent drawing of 'joy stick' for airplanes." Could you give me either the date of issue or the number of this patent? I have often wondered when the modern stick control for airplane first came into use, but most aeronautical books do not mention the inventor. I saw it suggested one time that the word "joy stick" came from the name of an Englishman named "Joyce"; this seems rather far fetched.

—C. E. PEARCE,
Head of Machine Design Department
Kansas State College

The United States patent for the "joy stick" was issued to Robert Esnault-Pelterie of Boulogne-Sur-Seine, France, on November 3, 1914, and bears patent No. 1,115,795. The application was filed in the Patent Office on January 16, 1908.

Claim 9 of the patent reads as follows: "In an aeroplane, the combination of means for producing lateral stability, means for producing longitudinal stability and a single vertical lever for operating both said means for producing lateral stability and said means for producing longitudinal stability, said lever being mounted upon an universal joint and being oscillatable in every direction."

In an infringement suit against the government, claim 9, as well as claims 2, 5, 6, 7 and 8, were held by the Supreme Court to be valid and infringed. This decision may be found in 303 U. S., Page 26, decided January 31, 1938 under the heading, United States v Esnault-Pelterie. —ED.

" . . . rapid selection of gear ratios"

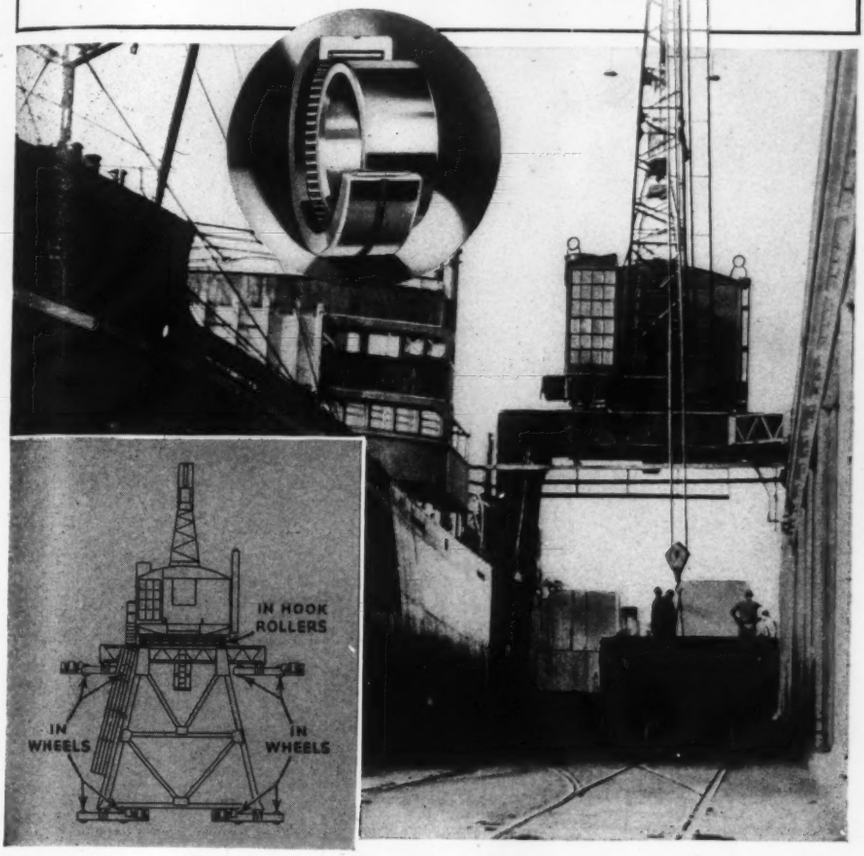
To the Editor:

As pointed out by Mr. Binder in your December issue, one may obtain the whole number of teeth in the gear and in the pinion of a mating pair, to equal any specified ratio, by the use of continued fractions. That arithmetic process enables one to attain any degree of closeness desired by simply making the whole numbers in the numerator and in the denominator large enough.

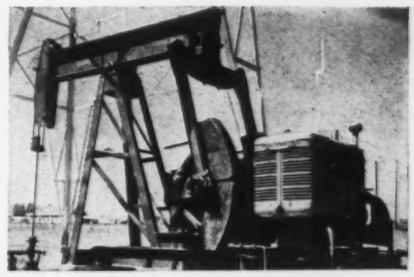
Another method, not as accurate, but generally more rapid and practical when exact ratios are not obtainable anyway, is the slide rule method. In using the slide rule, one need only remember that for any given setting of the slide, all numbers in juxtaposition bear one and the same ratio to

IN THE NEWS

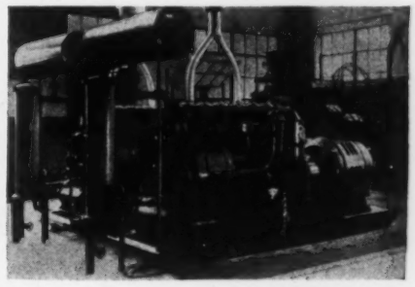
WITH BANTAM BEARINGS



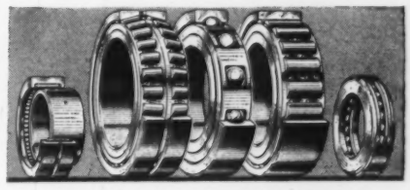
SPEEDY SHIPMENT OF WAR MATERIALS is a factor of vital importance in the program of the United Nations. Supplies are quickly loaded on shipboard by this revolving gantry crane built by American Hoist & Derrick Company. Crane is equipped with three hoisting drums, one lifting 15,500 pounds at 300 feet per minute, the others with a capacity of 10,000 pounds at 270 feet per minute. 20 Bantam Quill Bearings are used on travel mechanism, as shown in drawing, and on the wire rope blocks—another instance of the ways in which Bantam Bearings are rendering efficient, reliable performance in serving every phase of the Victory program.



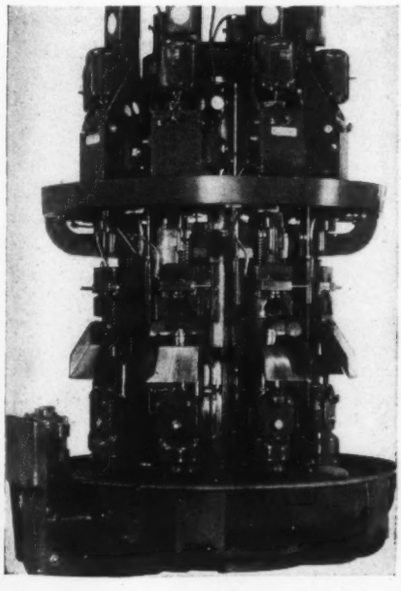
IN OIL WELL PUMPING UNITS, Bantam Quill Bearings are used by leading manufacturers to assure quiet, efficient operation, long service life, minimum need of attention. Cabot Shops, Inc., installs these compact, high-capacity units on equalizer and center bearings of its larger pumpers, obtains the advantages of anti-friction construction throughout.



ECONOMICAL POWER GENERATION is assured by modern engine and generator design. Developing 115 KW each in continuous 24-hour operation, these two generating units are powered by Murphy Diesel Company's 215 HP engines, with Bantam Quill Bearings in the generator drive assembly. For further information on these low-cost, high-capacity bearings, write for Bulletin B-104.



BANTAM'S ENGINEERING COOPERATION is especially valuable in meeting new and unusual requirements. Bantam makes every major type of anti-friction bearing—straight roller, tapered roller, needle and ball. Bantam engineers aid in the selection of the type that best suits your application—or design special bearings that meet your requirements. If you have a difficult bearing problem, TURN TO BANTAM.



SPEED AND ACCURACY are essential in machine tool operation—and Bantam's broad experience in bearing design and manufacture contributes to both these qualities. In this eight-station continuous drilling machine built by The Foote-Burt Company, the entire column rotates on a Bantam Ball Thrust Bearing measuring 27" O.D. by 22" I.D. Here is a typical example of Bantam's skill in the design of large bearings for heavy-duty applications.

BANTAM BEARINGS

STRAIGHT ROLLER · TAPERED ROLLER · NEEDLE · BALL

BANTAM BEARINGS CORPORATION • SOUTH BEND • INDIANA

QUALITY

WITH A 20 YEAR RECORD

The twenty years of making quality tracing cloth behind Arkwright is *your* guarantee of quality today!

Twenty years of testing in Arkwright laboratories . . . of insistence on the highest quality raw materials and the highest standards of manufacture have prepared Arkwright for the present emergency. In spite of the vital need for speed and mass production, you can order Arkwright Tracing Cloths today with the same confidence in quality . . . the same assurance of rapid delivery that has made Arkwright the leading American producer of tracing cloth for twenty years. Arkwright Finishing Company, Providence, R. I.

Arkwright
TRACING CLOTHS

each other. Therefore, it is simply necessary to set the slide to the ratio desired and read off all whole numbers that are contiguous.

For example, assuming that two gears are required to run as closely as practical to the ratio $\pi/1 = 3.1416/1$. With the slide rule set to divide 3.1416 by 1, the ratio of numbers anywhere on the D scale to contiguous numbers on the C scale would always be in the same ratio. Starting to inspect the C slide at 12 teeth (the smallest number of teeth considered for the pinion) no whole number of teeth for the gear is contiguous to it. The same is true for 13 teeth. But for 14 teeth, a whole number, 44, is closely contiguous. If strong teeth are needed, this ratio must be used. Proceeding along the scale, 21 to 66 and then 28 to 88 are the next whole numbers having the same ratio. Before going further, we must stop to consider whether or not the number of teeth is now becoming too large and their strength too low for the loads to be imposed upon them. That is another matter, although a pertinent one.

To find the degree of accuracy of any ratio, it would be necessary, as in continued fractions, to carry out the division indicated and then calculate the error.

Taking the first three ratios obtained, 44/14, 66/21 and 88/28 their values are 3.14285, 3.14285 and 3.14286 respectively. The differences between these values and 3.1416 are .00125, .00125 and .00126. These differences divided by 3.1416 are the percentage errors which reduce to .039, .039 and .04 per cent.

A significant error is always noticeable by the lack of coincidence of the juxtaposed divisions. In fact, the magnitude of the error can be easily judged directly from the slide rule.

—FREDERICK FRANZ

" . . . prevents excess recess"

To the Editor:

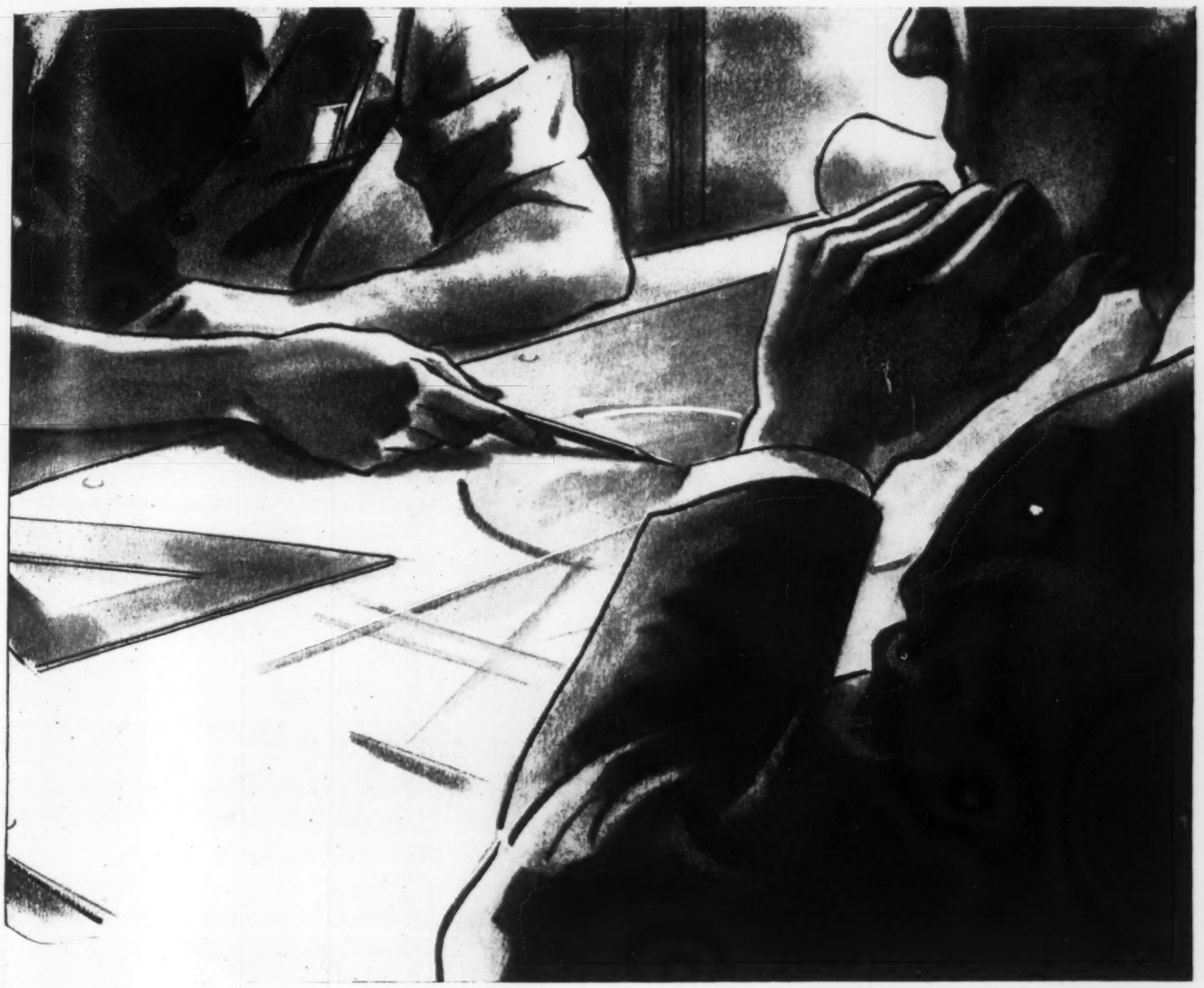
Due to the pressure of ever-increasing demands upon engineering departments today, designs are often released for production which have not been thoroughly analyzed regarding accessibility of various parts that may require replacement or adjustment.

The present shortage of competent men to staff maintenance departments has put a ceiling on available man-hours in most manufacturing plants today. Equipment that can be serviced readily is a boon to such departments. Idle time for production equipment must be kept to an absolute minimum.

The total cost of such design oversights would be impossible to estimate, but undoubtedly it runs into a sizable amount. More emphasis should be put upon this requirement in the design departments of our machinery manufacturers.

Let us remember "easy access prevents excess recess."

—C. E. SHIRMER, *Chief Engineer, Hoist Div.*
Robbins and Myers Inc.



No. 4 of a series designed to help Industry

BLUEPRINTS for VICTORY

THERE IS NO QUESTION about the ability of United States Industry to *produce*—both as to quality and quantity. But no factory can produce a product better than blue-prints call for. Today we are in the position of placing our finest war-equipment designs on a mass production basis. Standardization is the keynote. Today's job is the production man's.

But there is still tomorrow's job that MUST be done today: The design of better products—whether for war or for the peace that will follow.

Today production of Cone-Drive gearing is 100 per cent for a fighting war, at a rate that would not have been believed possible a few years ago. Tomorrow, that production of *Cone-Drive* gearing, with its higher load capacity, greater life, lighter weight, greater compactness and ease of lubrication will be available for Victory in Peace as well as War.

We need Blue-Prints for Victory in either case.

If you don't know the Cone-Drive story, send for Bulletin No. CW 41-A (for executives), or manual No. CW 41 (for design engineers).

CONE-DRIVE DIVISION MICHIGAN TOOL COMPANY
7171 E. McNichols • Detroit, U.S.A.

NEW
WATER
PUMP
SEAL

John Crane Bellows seal and washer, without driving well, showing seal and washer without ears.

By JOHN CRANE

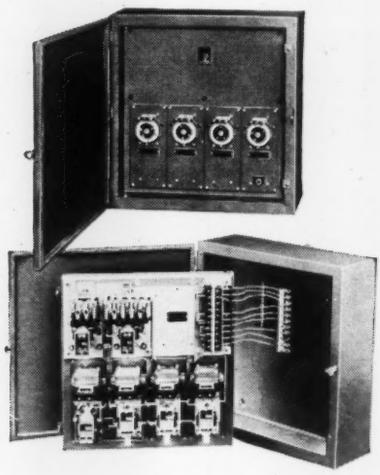
History—is written by the new John Crane Bellows Seal—nothing like it has ever been made before . . . Exclusive features! . . . Record-breaking performance under severe pressures, temperatures and fluids . . . Send your blue-prints and operating conditions. Ask for literature.

CRANE PACKING COMPANY, 1800 Cuyler Ave., Chicago
CRANE PACKING COMPANY, Ltd., Hamilton, Ontario, Canada

New PARTS AND MATERIALS

Resistance Welder Control

PLACING all electrically energized parts behind a protective panel, eliminating any danger of shock while timing adjustments are being made, a new resistance welder control has been introduced by the Industrial Controller division of the Square D Co., 4041 North Richards street, Milwaukee. Cali-



brated timer adjustments are completely accessible on panel front. This new design provides a separate pneumatic timing device for each step of the welding cycle. Timing periods from 3 to 100 cycles are obtained by turning a small knurled wheel. Interiors "swing out" to expose operating parts. A separable connector permits panel to be removed without disturbing external connections. In this new line eighteen NEMA standard types of weld and sequence timers, plus a wide range of accessories, are available to fill any welder requirement.

Arc Resistant Material

LAMINATED insulating sheets, tubes and rods of recently developed materials are being made by Formica Insulation Co., Cincinnati. Having an arc resistance approximately ten times that of previously available laminated insulating materials they are provided in all the usual laminated grades

Scientifically Controlled Manufacture
assures unsurpassed serviceability

• Complete laboratory and metallurgical control over charging ratios, and melting and pouring temperatures—the use in manufacture of virgin metals only thus holding impurities to negligible limits—and rigid inspection, assure at Buckeye, the production of an exceedingly high quality product, each piece of which month after month measures up fully to Buckeye's exacting specifications.

Buckeye bearings are free from porosity or blow holes. The component metals are evenly and thoroughly disbursed to all parts of the bearings, assuring a maximum of long satisfactory service.

Buckeye bearings, reflecting the advantage of this skilful, painstaking, experienced manufacture include 1088 stock sizes of fully finished ready-to-use phospher bronze bearings, one or another of which is the proven time-tested answer to most bearing requirements—560 sizes of cored and solid, rough and finished maintenance bars in the 13″ length introduced by Buckeye that cuts to size with a minimum of waste—Buckeye graphited bearings—and Buckeye "Specials" in a wide variety of IDs, ODs and lengths to customers' blueprint in any desired bearing metal analysis, slotted, split, drilled or threaded, with or without lugs, flanges, collars, etc., to meet widely different bearing requirements.

No order is too big or too small for Buckeye.

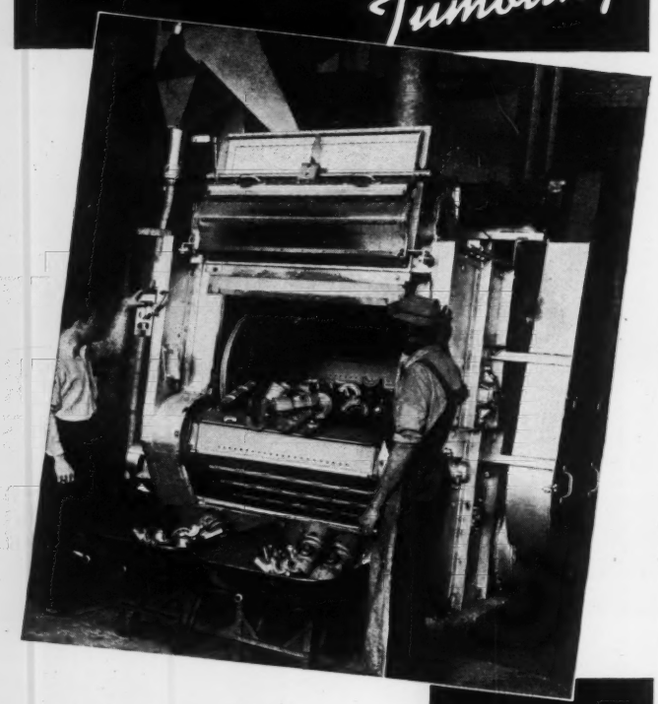
Buckeye
BRASS AND MANUFACTURING COMPANY

BRONZESMITHS SINCE 1900

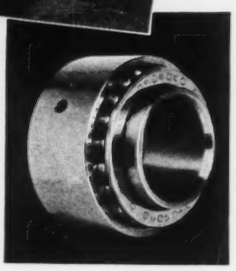
6412 HAWTHORNE AVE. CLEVELAND, OHIO

BRONZE SLEEVE BEARINGS • STANDARD SIZES OR TO CUSTOMERS' BLUEPRINT IN ANY RECOGNIZED BEARING METAL ANALYSIS

RBC helps keep
WHEELABRATORS Tumbling



Hundreds of these
WHEELABRATOR TUMBLAST
Machines—manufactured by
American Foundry Equipment Co.
—and now in service—are equipped with



RBC ROLLER BEARINGS

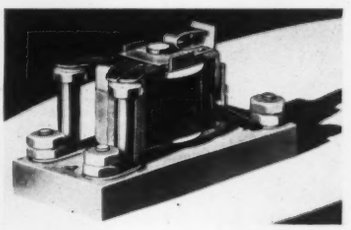
For 7 years RBC Anti-Friction Bearings have helped American Wheelabrators hold down their customers' operation and maintenance costs. These bearings used in the heart of the machine, the apron conveyor shafts, take the punishment of the continual tumbling of heavy castings. American reports, ". . . the bearings are very acceptable . . . and their use in the many machines in service is a recommendation of their value to us." On any problem affecting smoother, more economical operation of moving parts, put it up to RBC Roller Bearings. Send for Catalog with full engineering data.

ROLLER BEARING COMPANY *of* AMERICA
TRENTON . . . . NEW JERSEY

—paper base, canvas base, muslin base and fiberglas base. Under the American Society for Testing Materials arc-resistance test, this material will stand up from 130 to 190 seconds in the fiberglas grade, in comparison with previous materials withstanding this test only for from 13 to 18 seconds. Arc resistance is an important quality in materials which engineers are seeking to replace some of the critical and now unavailable materials.

Lightweight Aircraft Relay

BUILT to meet United States Army Air Corps specifications, the lightweight aircraft relay announced by General Electric Co., is designed for operation at high altitudes under severe vibration conditions. Weighing only 4½ ounces, the relay is 3⅛ inches long, 1⅝ inches high, and 1⅜ inches wide, and can be mounted in any position. It is designed for mechanical frequencies of 5 to



55 cycles per second at 1/32-inch maximum amplitude (1/16-inch total travel) in any direction, and for altitudes from sea level to 40,000 feet. Ambient temperature ranges from —40 Cent. to 93½ Cent. Designated as CR2791-A100A, the relay has a current rating of 25 amperes at 12 or 24 volts. Single-pole, normally open contacts will stay open when coil is not energized and closed when coil is energized at rated voltage even when subjected to linear acceleration of 10 times gravity in any direction.

Welding Sequence Timer

ANNOUNCED by Westinghouse Electric & Mfg. Co., East Pittsburgh, the new weld and sequence timer can be used in automatic resistance spot, butt or projection welding. Overall dimensions of the unit is 17¼ x 12 x 12 inches. Housed in a steel wall-mounted enclosure of black crinkled finish, the timer weighs 60 pounds. On the front steel panel are mounted individual timing circuit, adjusting potentiometer knobs and dials, repeat and nonrepeat switches, and tubes. Control transformer is wound for 115, 230, 460, 515 volts, 56 to 60 cycles. Solenoid relay is rated at 25 amperes at 110 or 220 volts and 10 amperes at 440 or 550 volts. Standard foot switch control voltage is 115 volts except when 24-volt circuit operation is specified. Fully electronic, the timing circuit consists essentially of a resistor capacitor circuit whose charging rate is adjustable by varying a resistor. Voltage of the circuit is applied to the grid of a

Official U. S. Navy Photograph

P.T. BOAT"

—that's Hele-Shaw Fluid Power

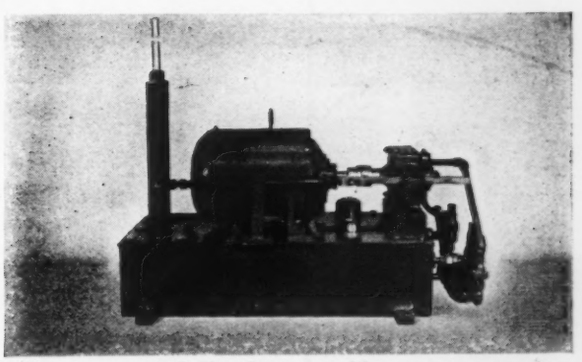
Aids location and relocation of machines. Remote control is a big advantage in powder plants

There's no reason why the location of the power unit of a machine should be a stumbling block—not if the machine can be operated hydraulically. Hele-Shaw Fluid Power solves the problem neatly. Hele-Shaw Fluid Power, being oil under pressure from a Hele-Shaw Pump, is simply piped from the pump, which has been placed at any convenient point, to the driven machine. The unusual flexibility of locating the pump is a real help in assembling new plants quickly, changing over existing plants, operating machines by remote control. Manufacturers of explosive products, especially, will appreciate the great advantage of driving machines from a Hele-Shaw Pump located at a distant, safe point . . . connected only by pipes. It pays to know all the advantages of Fluid Power described in our complete catalog. Write for your copy.

THE

Hele-Shaw

Fluid Power Pump



Shell Loading. This Hele-Shaw Pump is used by a munitions manufacturer for loading shells by remote control. Shell loading is done in one room. Pump and operator are in a separate room, from which he guides the loading by means of a mirror set in the separating wall.

OTHER A-E-CO PRODUCTS: TAYLOR STOKERS, MARINE DECK AUXILIARIES, LO-HED HOISTS

AMERICAN ENGINEERING COMPANY

2502 ARAMINGO AVENUE PHILADELPHIA, PA.

SAVE MATERIAL—save stock—save money as well by making machine parts *less bulky!* Pack more holding-power in smaller parts, narrower flanges, more compact assemblies! Use ALLEN Hollow Screws for further streamlining and reducing structural bulk!

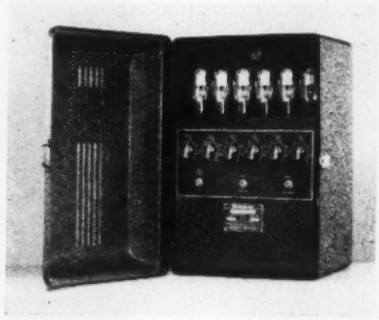
The greater strength of Allen screws permits *smaller* screws to be used. . . Their internally-engaging hex keys require *less room* for wrench-movement in setting up. . . The keys themselves are the most economical form of wrench possible to make,—the most *saving* in metal.

Utilize these Allen features to help Uncle Sam hold on to his precious bundle of stock. He cannot have it wasted; he needs every ounce of metal to hurl at the enemy. Even a *little* saving on *each* machine adds up to the weapons that WIN.

Your local Allen Distributor will accommodate you to the utmost of his capacity and available supplies.

THE ALLEN MFG. COMPANY
HARTFORD, CONNECTICUT, U. S. A.

thyratron tube so that after a predetermined charging time has elapsed the thyratron is energized and operates the relay. Total time of a

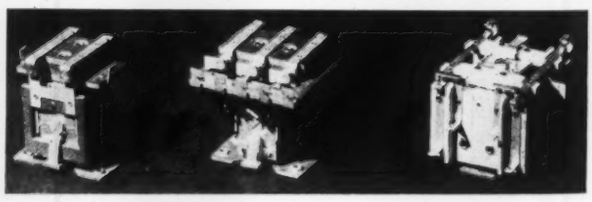


weld is divided by the timer into various intervals in which the welder goes through its operating sequence and includes a "weld" period of 3 to 30 cycles when full welding current flows. Timing facilities permit intermittent heating and cooling steps of from 3 to 30 cycles when welding thick plates, brass, or stainless steel.

Three Aircraft Relays

DESIGNED particularly for aircraft applications where light weight, ability to withstand severe vibration conditions, and operation at high altitudes at rated current are of importance, General Electric Co. has announced three new relays, consisting of a high-voltage relay, two single-pole relays, two two-pole, and two three-pole relays. This line of relays is also applicable to tank installations, and for use in a wide range of ambient temperature—from —40 Cent. to +95 Cent. Suitable for use at rated current at altitudes from sea level to 40,000 feet, they are corrosion-proof, meeting Navy 200-hour salt-spray tests, and are good for mechanical frequencies of 5 to 55 cycles per second at 1/32-inch maximum amplitude (1/16-inch total travel) applied in any direction.

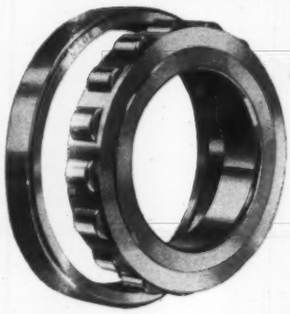
SINGLE-POLE RELAY: Available in two forms, one a single-circuit type with one normally open contact and the other a two-circuit type with one normally open and one normally closed contact. Having a



maximum continuous current rating of 20 amperes at 12 or 24 volts, and a maximum make or break rating of 100 amperes at 12 or 24 volts, the relay weighs 3 ounces in the normally open form, and 3.4 ounces in the other. Relay measures 1¾ x 1⅝ x 1 5/16 inches.

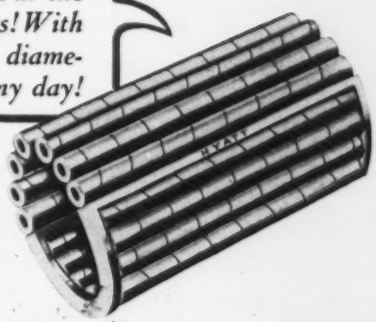
HIGH-VOLTAGE RELAY: For use with aircraft ra-

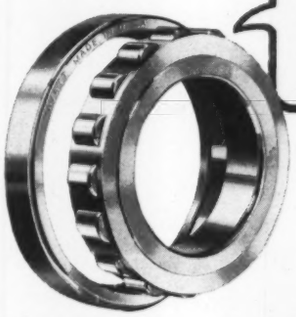
Said 1942 to 1892



1942: *Hi, Old Timer!*

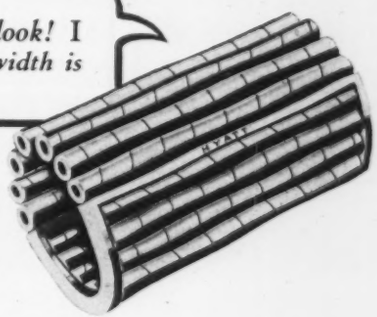
1892: *A little more respect, please. I'm the daddy of our great line of Hyatt Bearings! With a tolerance of .010 in my wound roller diameters I was the Number One bearing of my day!*

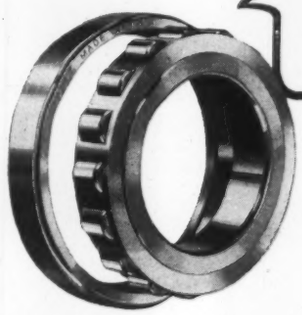




1942: *Okay Dad, but with my modern design and close tolerance of one ten-thousandth of an inch, I'm the "fair-haired boy" today.*

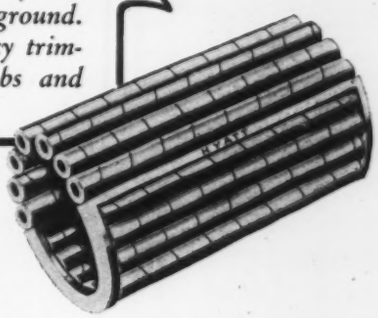
1892: *Hmph! But how skinny you look! I had a width of 6-7 inches while your width is only 1-1½ inches, young fellow.*

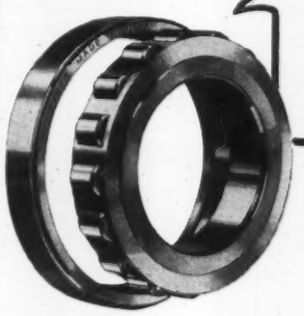




1942: *I'm streamlined, old man, but what capacity I possess. And I'm a pretty slick article with my inner and outer race, and my ultra finish.*

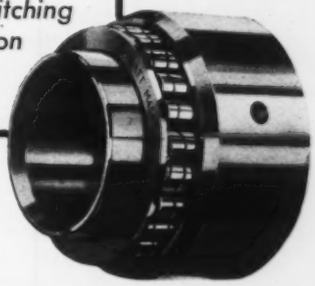
1892: *I know . . . I've watched you develop over fifty years. Sure I was made of only low carbon steel and my finish wasn't even ground. In my day, we didn't have all the fancy trimmings—but we handled the tough jobs and handled them well!*





1942: *I appreciate all that, old fellow, but think how out-of-place you would be today with that crude half-spacer roller retainment as compared to my swanky bronze cage and microscopically finished solid rollers and races.*

1892-1942: *You're right, lad. But look me over now. Other than in roller design I've changed considerably during these years. And I'm still in there pitching with you where applications call for my lubrication features and shock load advantages. So—give credit where credit is due!*

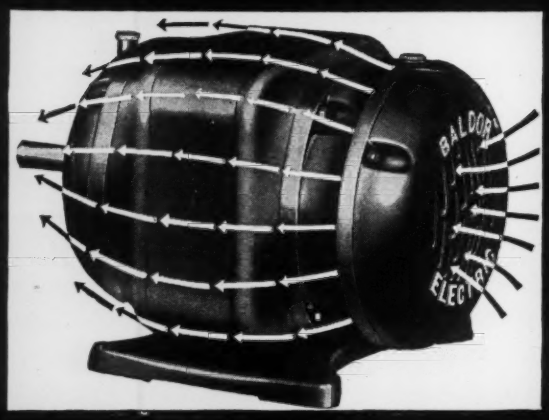


THE 50TH YEAR OF

HYATT ROLLER BEARINGS

HYATT BEARINGS DIVISION, GENERAL MOTORS CORPORATION, HARRISON, NEW JERSEY

BALDOR
BETTER MOTORS



Illustrating forced air-movement over entire exterior of motor frame

Streamcooled DESIGN
—a Superior BALDOR feature

BALDOR Streamcooled design provides totally enclosed motors with an unfailing, CAN'T CLOG cooling system that assures permanent cool-running performance.

These are ball-bearing motors, with glass insulation to withstand higher temperatures and provide more H. P. in smaller frame sizes.

These and many other features at NO EXTRA COST to you.

BALDOR ELECTRIC COMPANY, *St. Louis*
Motor Specialists for more than 21 years
Representatives in Principal Cities

BALDOR
ELECTRIC

dio transmitting equipment, the high-voltage relay makes use of ceramic insulation and double-break contacts which permit control of circuits as high as 1000 volts direct current, and 1/10-ampere at 500 volts direct current. Arranged for double-pole, double-break operation. Relay is 2-5/16 inches wide, 1-1/16 inches deep and 1-1/16 inches high.

TWO AND THREE-POLE RELAYS: Provided in two forms, one with normally open circuit per pole and the other with one normally open and one normally closed circuit per pole, these relays have maximum continuous current ratings of 8 amperes at 12 or 24 volts, and maximum make or break ratings of 25 amperes at 12 or 24 volts. Both two-pole forms are 1-25/32 inches wide, 1⅜ inches deep, and 1-21/32 inches high, and weigh 3.5 ounces. Overall dimensions of the three-pole forms are 1-25/32 x 1⅜ x 1-21/32 inches; weight 3.75 ounces.

Twenty-Four Hour Time Switch

DESIGNED to meet the increasing demand for a time switch for single cycle operations where only one automatic "on" and "off" operation is required in any twenty-four hour period, International Register Co., 2620 West Washington boulevard, Chicago, has announced its model TS-41 Inter-Matic time switch. This electric time switch, operated by a self-starting synchronous motor, is rated at 35 amperes 115-230 volts, non-inductive load, or 35 amperes 115 volts, 17 amperes 230 volts, inductive load, alternating current. Switch is single pole, single throw with silver snap-action contacts. The case is 21 gage drawn steel, measuring 7¾ x 5 x 3 inches, and finished in black scratch resisting enamel. The timing range is from a minimum of 15 minutes to a maximum of 24 hours. Settings are visible through a window in the cover. The switch has an automatic reset mechanism which resumes time cycle regardless of whether switch has been turned off or on manually. Models of the switch are available for operation on 60, 50 or 25 cycles. Entire mechanism may be removed by loosening one screw, with all parts easily replaceable.

Colored Transparent Finish

FOR use on polished metal, a colored transparent finish is being produced by Maas & Waldstein Co., Newark, N. J., as a substitute for electroplat-

CHAIN—CHAIN—CHAIN —miles and miles of Link-Belt chain—used annually for industry's mass-production conveyors and for the efficient transmission of power!

Yet today, Link-Belt chain is playing an even more vital part in this industrial program — aiding American manufacturers to produce at ever-greater speeds the essentials needed in the Nation's titanic production job of winning the war.

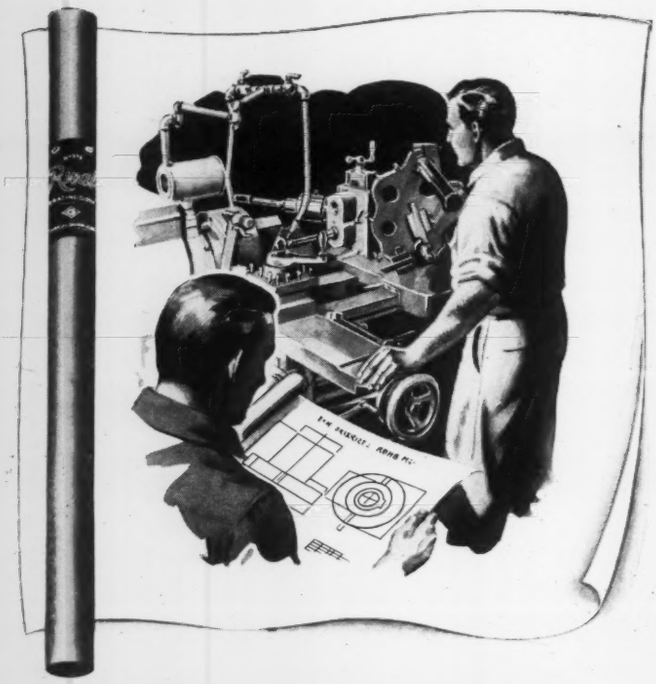
Link-Belt — since we gave to the world the first detachable chain, "Original Ewart Detachable Link-Belt," back in 1875—is conscious of its responsibility to make the best chain that brains can conceive, skill can produce and that money can buy. This trade mark on every link identifies our product.

LINK-BELT COMPANY, INDIANAPOLIS

CHICAGO • PHILADELPHIA • ATLANTA • DALLAS • SAN FRANCISCO • TORONTO

World's largest manufacturer of chains for conveying and power transmission

87.5 C



FASTER PRODUCTION

in every roll

PRODUCTION *starts* on the drafting board. Here is where the *wrong* kind of tracing cloth can slow up your operations . . . and where the *right* kind can help speed them. In thousands of drafting rooms today, production is getting off to a faster start because of Bruning Rival Tracing Cloth . . . the tracing cloth perferred by experienced draftsmen.

Rival has perfect uniformity of surface—which means no blemishes to hinder the draftsman's work. Rival is famous for its easy erasing—no time lost in eliminating smudges and troublesome "ghosts." Rival has a superior and lasting transparency not obtained with oils or wax—which means clearer, readable prints always. And Rival has exceptionally high tensile strength and durability to eliminate costly retracing.

We'd like to send you a sample of Rival—so that you can see and judge it for yourself. Find out why —and how—Bruning Rival can help *your* draftsmen win the battle for speed. Charles Bruning Co., Inc.

2042-253A

BRUNING

Since 1897

NEW YORK • CHICAGO • LOS ANGELES

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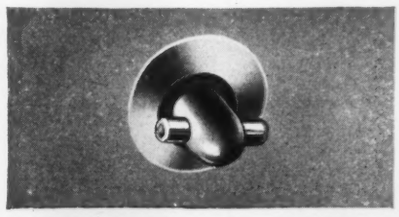
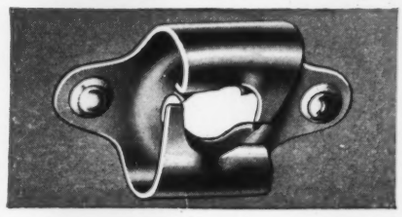
SPEEDS—SIMPLIFIES—AND PROTECTS A NATION'S DRAFTING

ing and bronze-powder finishes. This fast-color finish, consisting of a concentrated enamel of a desired color and a clear lacquer, makes polished metals resemble copper, brass, bronze, color-treated aluminum and steel, or other metals. Applied by spraying or roller coating, the finish can be obtained for either air drying or baking. Flat stock, when finished with certain grades, can be formed after baking. Two-color finishes can also be obtained by "relieving" operations.

Aircraft Cowling Fastener

TODAY'S requirement of increased strength for cowling and cowling fasteners due to increased speed of modern aircraft has been met by the design of a new fastener manufactured by United-Carr Fastener Corp., 29 Ames street, Cambridge, Mass. This fastener for use on engine cowlings, hand-hold covers, fairings and many other aircraft applications, is known as the Airloc. Shown in the

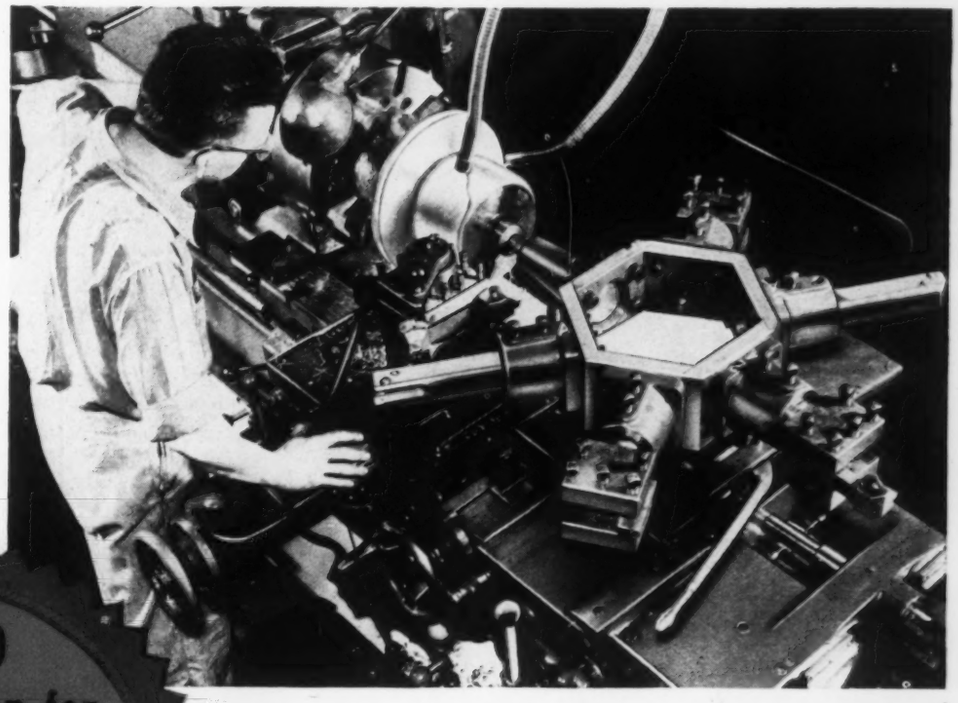




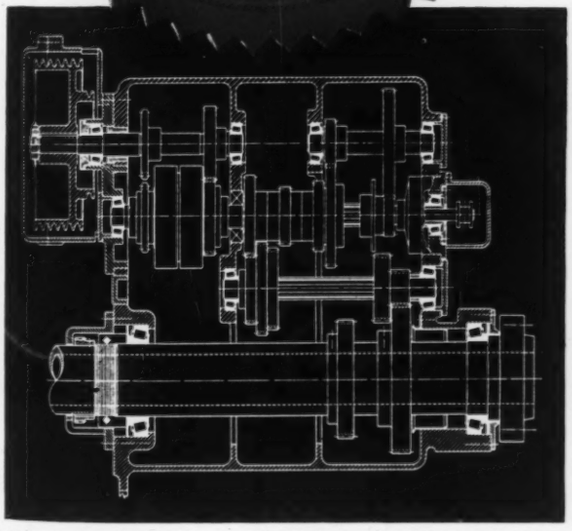
accompanying illustration in approximately full size, it is made up of two primary parts—a stud and a stud receptacle. The fastener has unusual ability to withstand the force of suction that tends to separate the sheets. In addition it has high shear strength, can withstand vibration, is easy to install, and does not require close tolerances on members to be joined. The load is not applied to the spring part of the fastening, which can be used on any combination of thicknesses.

Plastic Baking Enamel

ESPECIALLY developed for matching plastic parts to finished metal parts, a new plastic-seal baking enamel has been developed by Duralac Chemical Corp., 84 Lister avenue, Newark, N. J. Inexpensive plastics may be coated with this enamel to get any color desired. The finish, sprayed-on and baked in ovens or under infra-ray lamps, gives an attractive surface which is long lasting, resistant to moisture, oil, abrasion and many solvents such as alcohol. One coat is sufficient. Another grade of this plastic-seal finish is an air-drying lacquer for metal or plastic. This



SPEED and precision for the tools of Victory. Timken Bearings will make them tools of prosperity after the war.



Headstock of the Gisholt 2L High Production Turret Lathe showing the application of Timken Bearings on spindle and other shafts.

Heavy duty machine tools equipped with Timken Bearings form the backbone of American Victory production. They include lathes, milling machines, grinders, drilling machines, boring machines, gear hobbers, and specialized equipment of many different kinds.

The Gisholt 2L High Production Turret Lathe shown in the photograph is a good example of the speed and precision resulting from the use of Timken Tapered Roller Bearings.

When the photograph was taken, the lathe was machining wheel hubs of high carbon cast steel to a tolerance of .0005". With a cross-feeding hexagon turret and Gisholt standard tools it finishes two wheel hubs in the time previously necessary for machining one. Furthermore, many dimensions are held to even closer tolerances than are specified or were possible with the old method.

THE TIMKEN ROLLER BEARING CO., CANTON, OHIO

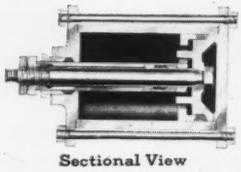
TIMKEN
TRADE-MARK REG. U. S. PAT. OFF.
TAPERED ROLLER BEARINGS

Manufacturers of Timken Tapered Roller Bearings for automobiles, motor trucks, railroad cars and locomotives and all kinds of industrial machinery; Timken Alloy Steels and Carbon and Alloy Seamless Tubing; and Timken Rock Bits.

Precision Cylinder Construction Gives You High Efficiency Use of Air Power

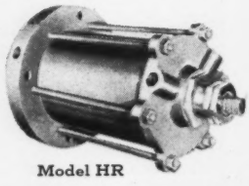
16 in. x 7 ft.
honed cylinder bore

The demands of continuous production make cylinder design more important than ever before. Hannifin pneumatic cylinder design incorporates the features that mean greatest useful work from air power—without leakage, with minimum friction loss, and simplest maintenance. Hannifin cylinders, including even the largest sizes, are bored and then honed, producing a cylinder bore that is straight, round, and perfectly smooth. The soft, graphite treated piston packing is easily adjusted from outside the cylinder, allowing the efficient piston seal to be maintained throughout the entire life of the packing. The piston can be repacked if necessary with standard graphited packing, always available.

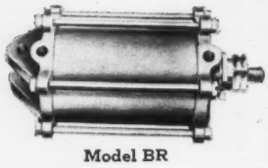


Sectional View

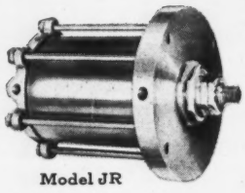
Hannifin pneumatic cylinders are built in a full range of standard mounting types, sizes 1 to 16 inch diameter, for any length stroke. Both single and double acting types, with or without cushion. Special cylinders built to order. Write for cylinder Bulletin 34-MD.



Model HR



Model BR



Model JR

Hannifin Manufacturing Company

621-631 South Kolmar Avenue • Chicago, Illinois

•

HANNIFIN

PNEUMATIC CYLINDERS

is available in a variety of gray shades closely resembling an aluminum finish. This material does not require a priority rating. Sprayed or machine-coated, the finish dries dust-free in ten minutes. One coat also will suffice for most purposes, presenting a durable finish for assembly-line production of metal parts.

•

CORRECTION: In the announcement in the April issue covering the E2Y1PC aircraft motor recently developed by Dumore Co., Fourteenth and Racine streets, Racine, Wis., an error occurred in the horsepower rating. This was given as 1/16 at 1500 revolutions per minute, whereas the new Dumore motor has a rating of 1/6 horsepower at this speed.

Engineering Dept. Equipment

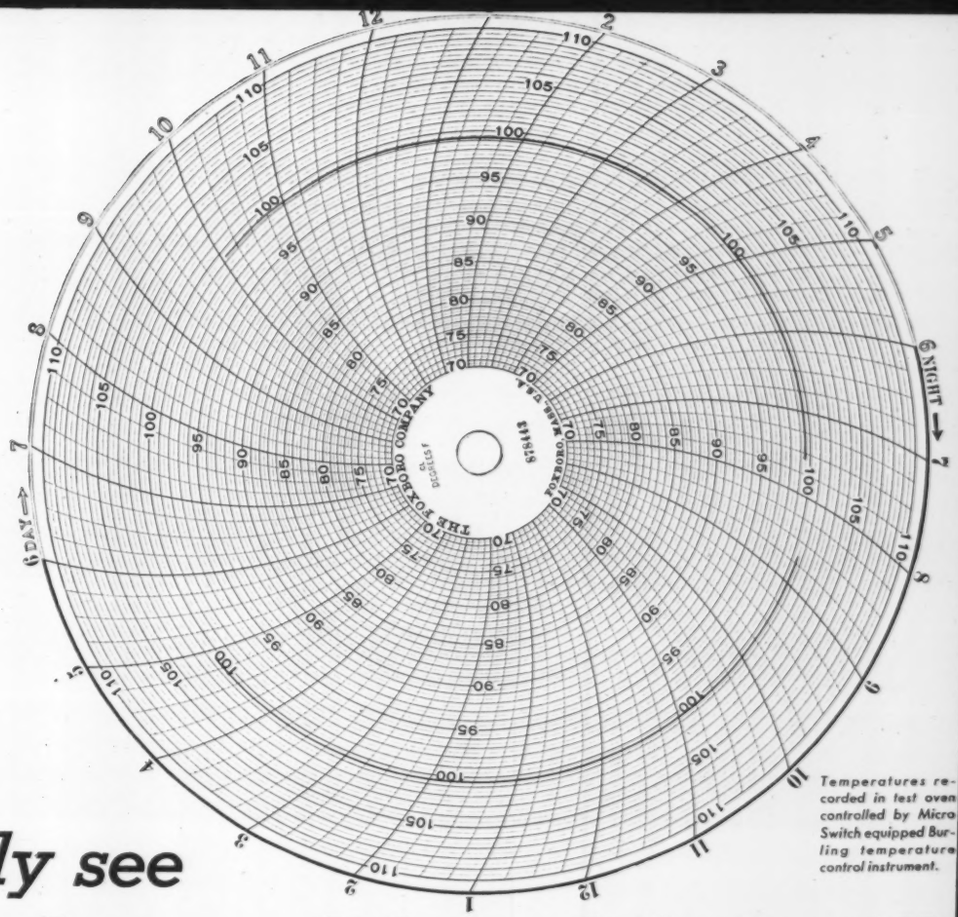
Three Photocopying Machines

THREE types of photocopying machines are being offered by Remington-Rand Inc., 499 Washington street, Buffalo, N. Y. Simple to operate, the machine produces permanent and durable copies which cannot be rubbed off or smeared by handling. Different weights and speeds of paper, map cloth, transparent cloth and transparent paper may be

used. A transparent copy of a blueprint can be produced on tracing cloth or paper, when original tracing is not available. The small portable desk model produces prints up to 9½ x 15 inches, and the larger one up to 20 x 24 inches. The continuous machine, which is the most recent, will reproduce any length of drawing with a maximum width of 42 inches. Photographic paper or cloth is fed continuously by the roll in this machine. The third type, the vacuum seal machine, produces a contact print up to 30 x 40 inches in size. In addition to pencil

Memo
MICRO SWITCH

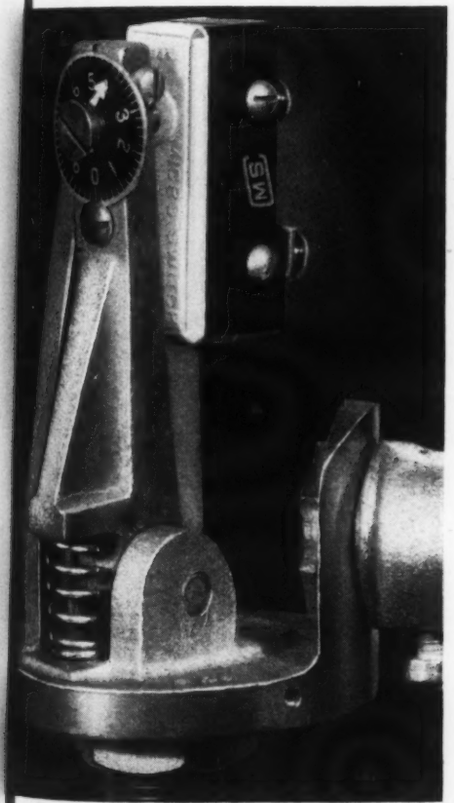
"They specified ±1/8° F.



Temperatures recorded in test oven controlled by Micro Switch equipped Burling temperature control instrument.

..you can easily see from the chart that we did much better!"

Herbert S. Burling, President
BURLING INSTRUMENT COMPANY
253 Springfield Avenue, Newark, N. J.



Burling Model V-I Micro Switch operated temperature control, shown with cover removed. The special V-I instrument that gave the extreme accuracy recorded in the chart employed a special Type WZ-R Micro Switch with .0001" movement differential.

In vitally important plants in this and other nations fighting for freedom, Burling instruments are controlling temperatures as low as —100° F., as high as 1400° F. The temperature chart reproduced here shows the extreme accuracy obtained with a special Model V-I instrument constructed for laboratory use, employing a special Type WZ-R Micro Switch with .0001" movement differential.

Burling temperature control instruments are activated by precision snap action Micro Switches. In the Burling Model VD-II, for example, two Micro Switches make it possible to control heating or cooling or both; to control the temperature and give either high or low limit control; to give 2 or 3-step control; to give floating control with reversing control motors; to give 2 or 3-speed control of auxiliary motors.

Burling Model VD-II (with cover removed).

Micro Switch dependability, precise action, and small size are ideal characteristics in this and hundreds of other process or product applications. The thumb-size basic Micro Switch weighs only an ounce, yet operates at the same point through millions of operations, on pressures as low as 1¼ ounces, and movements as low as .0002". Listed by Underwriters' Laboratories with ratings of 1200 V.A. loads, from 125 to 600 volts A.C.

Micro Switches can be supplied in a wide range of types and housings. Every engineer should have a copy of our Catalog No. 60. The operating principles and applications of Micro Switches are described in detail. New Catalog No. 70 describes Micro Switches for aircraft and similar applications.

Copyright 1942, Micro Switch Corporation

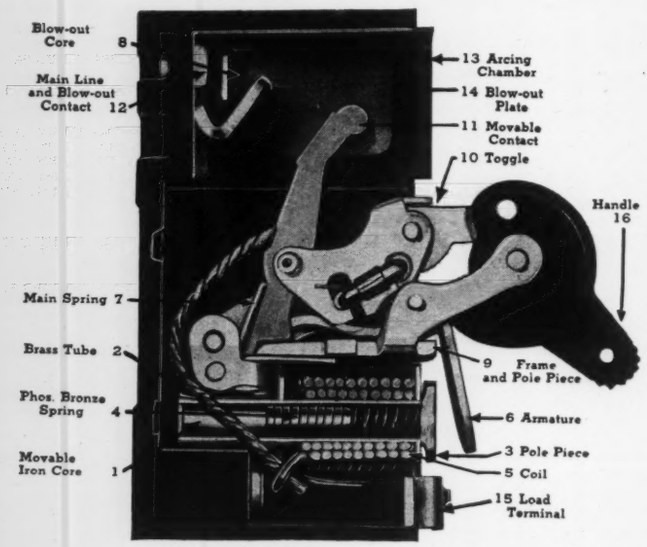
Micro Switch is a trade name indicating manufacture by Micro Switch Corporation.

MICRO MS SWITCH

Manufactured in FREEPORT, Illinois, by Micro Switch Corporation. Sales Offices: New York, Chicago, Boston

HEINEMANN "Re-Cirk-it" AUXILIARY BREAKERS

HERE'S WHAT MAKES IT TICK!



APPLICATION: ***"Re-Cirk-it"*** **magnetic circuit breakers** are the most inexpensive means of providing **'built-in'** protection against burnouts due to overload, low voltage, short circuit or 'locking'. Any type of equipment **using motors of 1/100 H. P. up to 1 H. P.** will be adequately protected by ***"Re-Cirk-it"*** AUXILIARY BREAKER.

OPERATION: ***"Re-Cirk-it"*** **magnetic circuit breakers** operate on load current only. The current carrying capacity and the minimum and instantaneous trip points are not affected by changes in ambient temperature thus assuring constant protection under all conditions.

True Inverse Time Delay in hermetically sealed unit allows passage of high current while starting motor; yet continued overload above the minimum tripping point opens the breaker in time inverse to the ratio of the current. **Instantaneous trip** on short circuit opens the breaker ahead of circuit protective device.

Send for Catalog 40 showing complete line

HEINEMANN CIRCUIT BREAKER CO.
Subsidiary of Heinemann Electric Co.
Est. 1888
113 PLUM STREET TRENTON, N. J.

or ink drawings the machines can be used to copy specifications, instructions, priority papers, or other printed material.

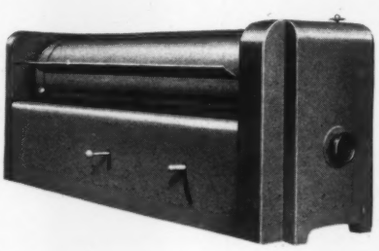
Mechanical Drafting Pencil

ANNOUNCED by the TEC Pencil Co., 9301 Olympic boulevard, Beverly Hills, Calif., is a new mechanical drafting pencil with a motor-driven lead pointing machine. As an exclusive feature, the pencil has a full length lead tube of spring brass which is driven downward into the chuck point by

a screw-operated mechanism, providing a positive grip on the lead and preventing any slippage or wabble. The pencil barrel, of lightweight plastic, is balanced and has the "feel" of a full length wood-encased pencil. The metal tip has been eliminated. This pencil is available also in the double-end type, providing two different hardnesses of lead in one holder, or a lead in one end and a scriber in the other. Lead can be furnished in nine degrees of hardness. The motor-driven lead pointer, which starts and stops automatically, provides needle-like drafting points in a few seconds and eliminates the operation of pointing with file or sand pad.

Welded Dark Room Printer

ENTIRELY new as to mechanism, C. F. Pease Co., Chicago, has introduced its new dark-room printer. Known as Model "D-3" the printer utilizes sliding contact which closely approximates vacuum contact. The contact glass is about 9 inches deep, lies parallel to width of machine, and is slightly curved to insure perfect contact. Of endless chain



type, the contact band is of black, specially-woven, two-ply, seamless fabric, preventing light leakage in the dark room. Light source consists of two 40-watt white fluorescent standard tubes, with a total current consumption of approximately 5 amperes. As practically no heat is developed by the tubes, it is unnecessary to provide artificial cooling. A "clam shell" type shutter, composed of two semicircular stainless steel shutters swung from the same hinge,

DOW

OUT OF THE SEA come millions of pounds of a marvelous weight-saving metal—magnesium—recovered by Dow from the water itself—to give speedier wings to our fighting aircraft today . . . and to inspire designers and engineers alike to free America from useless weight by unrestricted applications when victory is won.

THE DOW CHEMICAL COMPANY, MIDLAND, MICHIGAN

TRADE DOWMETAL MARK

MAGNESIUM

The Lightest Structural Metal . . . One-third Lighter Than Any Other in Common Use

and . . . it's Physical Properties are "MADE to ORDER" with ABSCO MEEHANITE

and Norton knows every one of these base castings for their popular Multipurpose Surface Grinders is exactly alike — ABSCO Meehanite takes the guesswork out of casting.

A machine tool for precision work, like this Norton Grinder, is more accurate . . . easier to operate . . . and lasts longer when its base has high damping capacity combined with strength and toughness.

Such desirable combinations of physical qualities are easily and consistently obtained in castings of ABSCO Meehanite — because *positive technical control* is possible with this metal.

CHECK THIS LIST . . . through our Selective Processing, a type of ABSCO Meehanite is available to fit your needs for any of these qualities:

1. ***Strength, toughness, high damping capacity***
2. ***Ability to stand shock or strain***
3. ***Free machining qualities***
4. ***Density and solidity for pressure castings***
5. ***Heat, acid and corrosion resistance.***

Let our technicians show you how ABSCO Meehanite will help you. Consult us now. Machine Tool Bulletin No. 9 sent on request.

THE AMERICAN BRAKE SHOE AND FOUNDRY COMPANY

BRAKE SHOE AND CASTINGS DIVISION

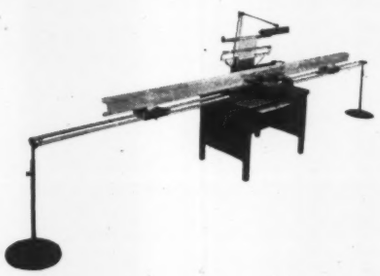
FOUNDRY
MAHWAH
NEW JERSEY

OFFICES
230 Park Avenue, New York, N. Y.
332 South Michigan Ave., Chicago, Ill.

controls the amount of printing light desired. A fine hair-line vernier type regulator screw is provided for extremely accurate adjustments. Driven by a ¼-horsepower variable speed motor through a controller mounted at right side, the printer has a two-speed gear shift which provides a speed range of approximately 2 inches to 3 feet per minute in low gear, and from 10 inches to 5½ feet per minute in high gear. All variable speeds in between these two ranges are accomplished by means of the controller. Overall dimensions of the machine are 22 x 60 x 18 inches; weight approximately 240 pounds.

Speedy Composing Machine

DELAY in producing blueprints in the drafting department has been cut 60 per cent by a special composing machine, recently announced by Ralph C. Coxhead Corp., 333 Sixth avenue, New York. After engineers and draftsmen produced drawings, the instructions, dimensions, specifications and data on manufacturing procedures had to be written in. With the new composing machine, a hand-lettering job which formerly took four to five days of a draftsman's time now is done by a typist



in half a day. The machine is an adaptation of the Vari-Typer, also developed by this company, and uses a typewheel instead of letters and symbols on single type bars. Changing of typewheel permits use of a variety of styles and sizes of alphabets. Spacing arrangement is also variable to permit use of alphabets with different width letters. A basket-type carriage with open ends is provided, making the machine adaptable to sheets of great size. This carriage and its supporting track have been extended to accommodate 20-foot sheets.

Improved Printing Paper

IMPROVEMENTS have been made by The Frederick Post Co., Chicago, in its ammonia dry-developed printing paper, which develops a deeper, sharper blue or red line print on a clean white background. Every roll is uniform both as to speed and color, and printing and developing machines do not have to be set to conform with variance of speed in different rolls of paper. This new faster and tougher paper, with its 50 per cent rag content basic paper stock, can stand up under creasing and hard usage.

There's just one foolproof solution to this draftsman's problem. And that's Micro-Weave All American Tracing Cloth. There are no bugs in Micro-Weave.

In spite of repeated erasure, Micro-Weave Tracing Cloth will take pencil smoothly and ink-over with minimum of feathering.

Its superior finish and fine hard surface mean higher transparency and maximum resistance to erasure.

Micro-Weave insures cleaner, sharper blue prints — in less time, with less effort, at less cost.

Send for generous size sample or ask your dealer.

THE HOLLISTON MILLS, INC.

NORWOOD, MASS.

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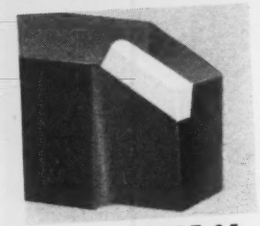
THE LINE BUG

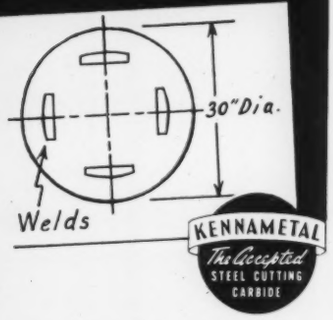
This persistent little termite leaves his feathery footprints on lines inked over after repeated erasure. You can make him harmless by using Micro-Weave Tracing Cloth.

Micro-Weave All American TRACING CLOTH

Micro Weave
MORE THAN 180 FLAWLESS THREADS PER SQ. INCH

GLASS HARD WELD SPOTS
Machined at 376 surface ft./min. with KENNAMETAL TOOLS





STYLE 35

Here is an outstanding example of the versatility of KENNAMETAL. Four lugs had been welded to the face of a large SAE 4160 steel casting, heat treated to 375-400 Brinell, in order to chuck it while facing one side and turning O.D. The lugs were then knocked off, leaving glass hard weld spots to be removed in the facing operation.

A 1½" square KENNAMETAL tool (Grade KM), with 35° neg. back rake and 15° pos. side rake successfully faced the work at 376 surface ft. min., with depth of cut of 1/16" and feed of 1/64". Two complete pieces were finished per tool grind.

KENNAMETAL is proving itself every day by similar performances on steels up to 550 Brinell, at high speeds, with maximum work between regrinds. Find out how KENNAMETAL tools can speed production in your shop. Write for the new 44 page pocket manual for KENNAMETAL USERS.

McKENNA METALS Co.
146 LLOYD AVENUE, LATROBE, PA.
FOREIGN REPRESENTATIVES U. S. STEEL EXPORT CO.
Exclusive of Canada, Great Britain and Possessions

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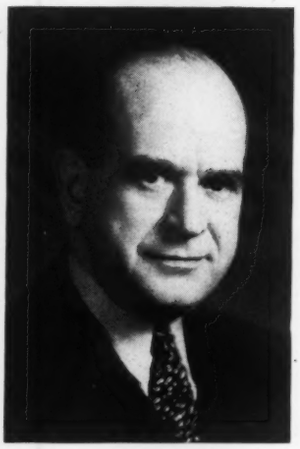
Quality Springs

LEE SPRING COMPANY, Inc.
30 MAIN STREET BROOKLYN, N.Y.

Ask About SCIENTECH Spring Service

MEN *Of Machines*



IN THE new division known as the tank section of the Fisher Body plant of the General Motors Corp., G. H. Kublin has been made chief engineer. Mr. Kublin's experience in engineering covers twenty-six years in the automotive industry. Included in this experience are six years with the Auburn Automobile as chief engineer. He resigned this position to accept one as assistant chief engineer of the General Motors Overseas Operations. Following this is his present appointment as chief engineer of the Fisher tank division which is now building the M-4 medium and M-6 heavy tanks for the government.

NOW vice president in charge of engineering design at Goodyear Aircraft Corp., Akron, O., Karl Arnstein is well known in the field of design and construction of aircraft and related structures, especially airships. He is, in fact, credited with the design of about 70 military and commercial airships, including the American ship, LOS ANGELES, and developed designs for two military rigid airships of 6,500,000 cubic feet capacity for the United States Navy

SOME HOMELY TRUTHS ABOUT

SWITCHES for HORSES and HORSEPOWER

SOME HORSES WILL GALLOP WITHOUT A "GIDDAP" . . . OTHERS NEED TO BE "SWITCHED" BEFORE THEY WILL RUN FULL SPEED . . . THE STARTING SWITCH ON CAPACITOR AND SPLIT-PHASE MOTORS HELPS TO BRING THEM UP TO SPEED AUTOMATICALLY . . . ON WESTINGHOUSE SMALL MOTORS THE IMPROVED STARTING SWITCH GIVES POSITIVE CHANGE-OVER FROM STARTING TO RUNNING CONNECTIONS . . . QUIETLY BECAUSE ANNOYING CLICKS ARE HUSHED BY CUSHIONED STOPS . . . ACCURATELY, BECAUSE THE SWITCH OPERATES BY CENTRIFUGAL FORCE . . . SURELY, BECAUSE EXPERIENCE, AND TESTS SHOW THAT THE SILVERED CONTACTS AND RUST-PROOFED STEEL PARTS GIVE THE MOST DEPENDABLE PERFORMANCE . . . THIS STARTING SWITCH IS JUST ONE OF MANY IMPORTANT FEATURES THAT MAKE WESTINGHOUSE SMALL MOTORS STAND OUT AND STAND UP.

J-03170

WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, EAST PITTSBURGH, PENNSYLVANIA

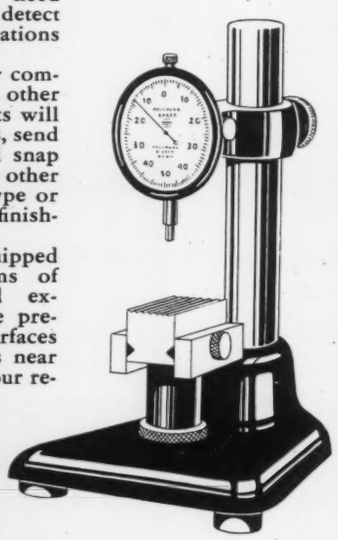
COMPARATOR and SNAP GAGE
ANVILS RESURFACED
by the ACME FLAT LAPPING PROCESS

★ Gage blocks and anvils, (serrated or plain), need frequent check-ups to detect the surface deviations caused by local wear.

To insure that your comparators, gages, and other measuring instruments will give *accurate* readings, send your comparator and snap gage tables, anvils, or other flat contacts of any type or style, to Acme for refinishing.

Because Acme is equipped to measure in terms of micro - inches, and experienced in extreme precision manufacture, surfaces can be finished to as near absolute flatness as your requirements dictate.

Be sure your measuring instrument anvils are accurate. Send them with any other *flat* parts to Acme for resurfacing today.



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USED IN
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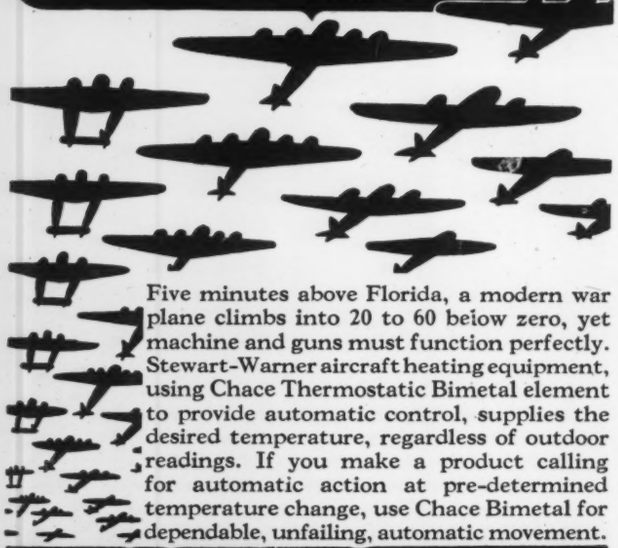
HERMETIC COMBUSTION HEATERS
FOR
AIRCRAFT
ANOTHER PRODUCT OF STEWART-WARNER CORP.
CHICAGO, ILL.



Five minutes above Florida, a modern war plane climbs into 20 to 60 below zero, yet machine and guns must function perfectly. Stewart-Warner aircraft heating equipment, using Chace Thermostatic Bimetal element to provide automatic control, supplies the desired temperature, regardless of outdoor readings. If you make a product calling for automatic action at pre-determined temperature change, use Chace Bimetal for dependable, unfailing, automatic movement.

W. M. CHACE CO.
1616 Beard Avenue - - - Detroit Mich.

Bureau of Aeronautics. Also, he directed the design and construction of the USS AKRON and MACON, pressure type airships, stratosphere balloons, lightweight streamline train, and heavier-than-air assemblies. Dr. Arnstein was born in Prague and received his education at the University of Prague and University of Aix-la-Chapelle. After serving as assistant professor at the Prague university he joined the engineering staff of the Zeppelin Co., Germany. In 1924 he came to America and became technical director of aircraft construction at Goodyear Tire and Rubber Co. A year later he was made vice president and chief engineer of the Goodyear-Zeppelin Corp., and then vice president and chief engineer of the Goodyear Aircraft Corp. He is a Fellow of the American Society of Mechanical Engineers and a member of the Institute of Aeronautical Sciences, and has contributed numerous articles to American and European technical journals on theory of structures, particularly as applied to airships, and on general engineering subjects.

YEARS of hard work have brought recognition to Anker K. Antonsen, recently made chief engineer in charge of the aircraft division of Menasco Mfg. Co., in addition to his present position as chief engineer in charge of the diesel engine division. Born in Denmark, he came to the United States in 1924. Joining Fairbanks Morse & Co., Beloit, Wis. in 1924 as design engineer, he later became chief designer of the company. From 1936 to 1938 he was chief engineer for the two-cycle engine division of American Locomotive Co., Auburn, N. Y., plant, resigning to become engine research engineer for John Deere Tractor Co. In two years he accepted the position of chief engineer of the diesel engine division of Menasco, which duties he will continue in addition to his new appointment. He is a member of the Society of Automotive Engineers and the Society of American Military Engineers.

♦

L. J. HAGA has joined the Kaydon Engineering Corp. as chief metallurgist. He formerly was associate professor of metallurgy at Illinois Institute of Technology.

♦

DON R. BERLIN, designer of the Curtiss P-40 pursuit plane, has joined General Motors as aeronautical engineer on the staff of O. E. Hunt, vice

EXACT CONTROL IS *Vital*..

— to maintain consistently uniform quality in the manufacture of stainless steel tubes, seamless and welded. A large and fully equipped chemical and physical laboratory, manned by graduate metallurgists, is basic to the exact control of production maintained at Globe Stainless Tube Company.

GLOBE TUBES

Globe Stainless Tubes are available in a wide range of sizes and analyses of chrome and chrome-nickel alloys. We will gladly cooperate with you on tubing problems and make recommendations, based on long experience, verified by practical and laboratory tests.

GLOBE STAINLESS TUBE CO.
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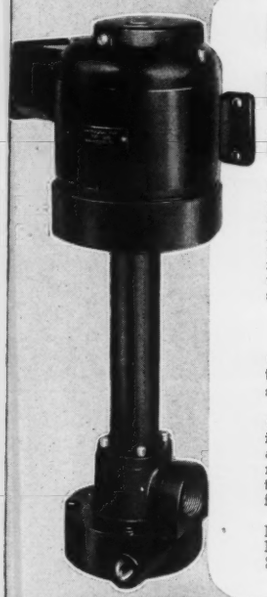
GLOBE STEEL TUBES

STAINLESS TUBES • BOILER TUBES • CONDENSER AND HEAT EXCHANGER TUBES • MECHANICAL TUBING . .

3000

EASTERN COOLANT PUMPS



Incorporate PUMP DEPENDABILITY in your machines . . .

Eastern Coolant Pumps on your machines assure a constant reliable flow of coolant compounds—at the proper rate of flow. Standard models offer a varied range of performance characteristics. Special types can be built to meet any specifications.

MOUNTING AN EASTERN

● Coolant Pumps offered in both tall and short types, for various shaped tanks.

● Two surfaces for direct mounting . . . complete line of mounting accessories . . . allow immersion mounting, external mounting on tank, or independent mounting in feed line.

For complete information, write Eastern Engineering Co., 144 Fox St., New Haven, Conn.

Drawing Production Shifts to A New High When You Use Hamilton AUTO-SHIFT TABLES

SPEED is an important factor in our all-out war effort and increased drawing production is one of the first steps to Victory. Draftsmen can do their best only when the proper equipment is provided for them.

Investigate today the advantages of Auto-Shift Drawing Tables. Write for circular No. 69 fully describing the new improved Auto-Shift Drawing Tables.

HAMILTON MANUFACTURING COMPANY MD-5/42
Two Rivers, Wisconsin

Send me circular No. 69 fully describing the new improved Auto Shift Drawing Tables.

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president. He was formerly director of military engineering of the airplane division of Curtiss-Wright Corp., Buffalo, N. Y.

♦

ALFRED MARCHEV has become connected with Republic Aviation Corp. as assistant to the president. Mr. Marchev resigned as chief engineer, works manager and director of Signode Steel Stamping Co. to take his new post.

♦

ORVIL S. TUTTLE has been named chief aircraft engineer for United States Plywood Corp., due to the company's increasing activity in the aircraft plywood production. He was formerly senior design engineer for Lockheed Aircraft Corp.

♦

GEORGE J. HIGGINS, Lt. Comdr., U.S.N.R., is on leave of absence from the University of Detroit where he was full professor and director of the department of aeronautical engineering. He is on active duty on the staff of the Post Graduate School of the United States Navy, Annapolis, Md., teaching aeronautical engineering.

♦

HAROLD S. OSBORNE, plant engineering, operation and engineering department of American Telephone & Telegraph Co., New York, has been nominated as president of American Institute of Electrical Engineers, New York.

♦

J. C. SHAW has been placed in charge of engineering work of the enlarged aircraft products division of Young Radiator Co., Racine, Wis. For the past five years Mr. Shaw has been engaged in general engineering work on aircraft accessories and has specialized in development of heat transfer equipment. This new division will be under the direct supervision of J. J. HILT, vice president.

♦

JOHN S. RICHARDS, formerly manager of the metallurgical department of American Steel & Wire Co., Cleveland, has been appointed director of research.

♦

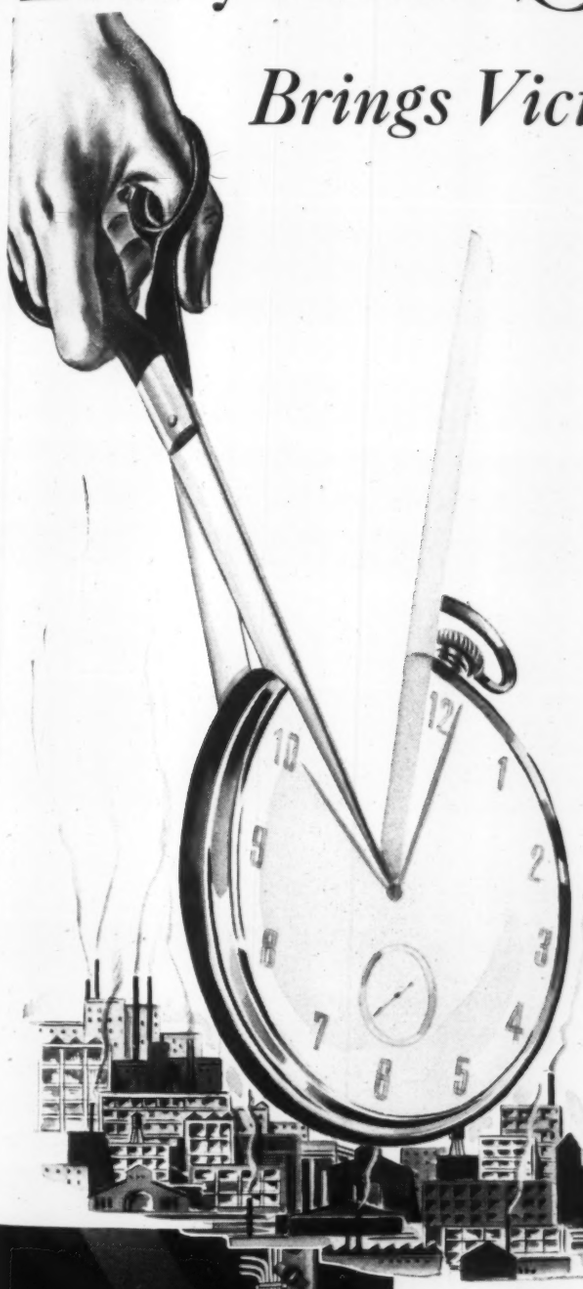
WAVERY A. REEVES and DR. C. W. SMITH, technical supervisor, supercharger department, General Electric Co., and S. R. PUFFER, designing engineer, supercharger department, have received Coffin awards from the company "For an outstanding group accomplishment in bringing the turbosupercharger enterprise through highly critical years to its present great value in the war effort."

♦

HUGO WEISSBRODGT, formerly general manager of International Harvester Co. Springfield, O., works, has been named chief of field operations for the War Production Board's Detroit region. He has served with the WPB Automotive branch staff since February. In his new position he will have supervision over WPB's Contract Distribution branch, including offices in Detroit, Toledo and Grand Rapids; and he will also direct the Michigan regional operation of the procurement and expediting section, the machinery and equipment section and the standardization and production section.

Every Hour *Saved* in Industry

Brings Victory One Hour Closer!



BACK in the days before Pearl Harbor a 60-minute hour was all right. Now everything is changed. More production minutes crowded into an hour means more hours saved in a day—and every hour saved brings victory that much closer.

For example: One manufacturer was using 35 seconds on the assembly line to fill differentials with grease. Alemite showed him how to meter the exact amount needed into each differential—*in 15 seconds!* A better job—under better control—in less than half the time! *That's crowding extra minutes into every hour!*

Give yourself this quick quiz: 1. Are *your* machines halted for lubrication? 2. Are breakdowns stealing vital production time? 3. Are power costs too high? 4. Is contamination a problem? 5. Are you having lubrication difficulties caused by heat, cold, or chemicals?

The chances are that an Alemite lubrication expert can help you increase your output—simply by pointing out where peace-time lubrication methods are *stealing vital hours* from war production. For quick action, wire or phone direct! No obligation!

ALEMITE

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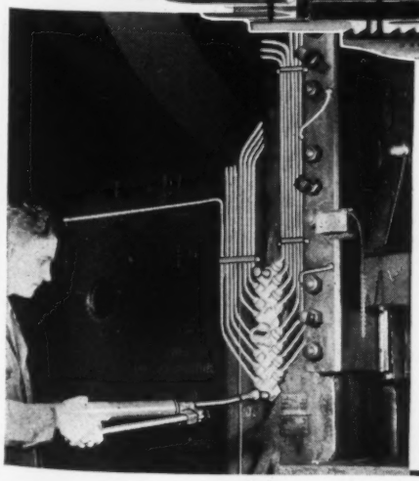
1804 Diversey Parkway, Chicago, Ill. • Belleville, Ontario

Another Product of STEWART WARNER

Industrial LUBRICATION

ALEMITE HELPS THE WORLD GO 'ROUND

Ask Anyone in Industry!



CENTRALIZED LUBRICATION

Cut Lubrication Costs with New Alemite Progressive Lubrication System

THE Alemite Progressive Lubrication System insures dependable, positive pressure lubrication from one central point. It speeds lubrication, promotes safety by bringing remote bearings into easy reach, *permits lubrication while machinery is in operation.* It may be serviced by either a power or manually operated grease gun.

From the standpoint of increased production afforded by machines of your manufacture, this system deserves your investigation. It is inexpensive and easy to install. And it invites regular, systematic lubrication, helping to keep service calls at a minimum.

Include VARIABLE SPEED Without Design Changes

Equip machines you build to meet today's demand for maximum production. IDEAL Variable Speed Pulleys require no change in your original design. Easily installed; mount directly on motor shaft. Low in cost.

FEATURES

Infinitely variable speed; speed ratios up to 3 to 1.
Belt always in alignment.
Full belt contact at all driving diameters.
Compact; light in weight; perfectly balanced.
Sizes up to 8 H.P.

This Machine Shows How Easily One Machinery Manufacturer Used

IDEAL VARIABLE SPEED PULLEY

Wide V-Belt Pulley permits infinitely variable control of work-speed between 15 and 54 cycles per minute.

FREE HANDBOOK—52 Page Manual full of Transmission Ideas, Illustrations and Engineering Data. Send for your copy today.

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PUMPS FOR ARMY • NAVY • AIR FORCE • MARINE • AND INDUSTRIAL APPLICATIONS

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Model M COOLANT PUMPS

Tuthill Model M internal-gear, positive displacement rotary pumps are doing an outstanding job, handling cooling oils on machine tools in war-time production.

MODEL M—A compact design with a built-in safety or by-pass feature. Suction and discharge zones are separated by hydraulically balanced shoes which (1) act as a by-pass by lifting off the rotor when the spring pressure (set between 10 and 20 p.s.i.) is exceeded—thus permitting chips and small particles of grit to pass through without injury to working parts; and (2) compensate for wear. Six sizes from 1 to 50 g.p.m.

MODEL MS (Stripped Pump)—This pump is the same as Model M without the supporting bracket. It saves material and space because it can be incorporated directly into your machine.

Write for complete Catalog describing these and other dependable Tuthill Pumps for Production Machinery and scores of war-time applications.

TUTHILL PUMPS

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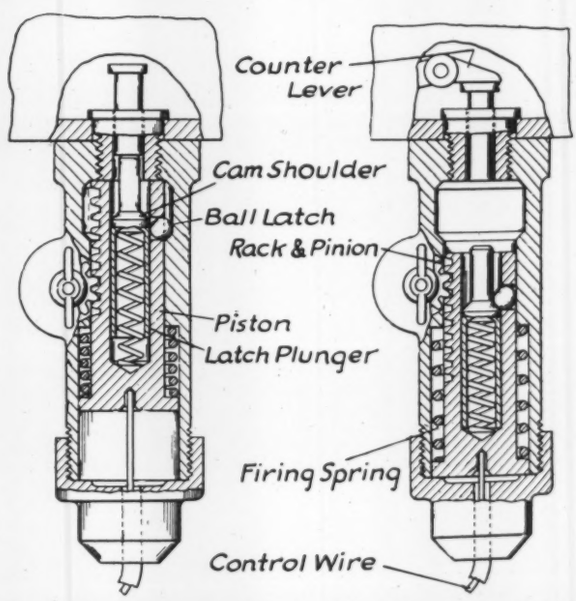
Noteworthy PATENTS

Boosts Mechanical Impulse

IN MECHANICAL pilot mechanisms such as counters, speed and quantity indicators, etc., it is often desirable to have these devices exercise a control function on the machine of which they are a part. It is, of course, possible to accomplish this end by electrical means. However, it is often more convenient that the entire control system be mechanically operated. This has been accomplished by means of a mechanism discussed in a patent assigned to the Veeder-Root company. The mechanism disclosed therein is designed to operate in conjunction with a counter on a textile loom. The counter measures the length of material as it is woven by the loom. When a pre-selected length has been recorded, the device is actuated.

Shown in the left-hand illustration is the mechanism in the cocked or firing position. To attain this position the piston is raised manually by means of the wing nut operating the pinion gear engaging the rack teeth formed in the side wall of the piston. As the piston is raised the ball latch comes into registration with the increased diameter in the upper portion of the housing. Under the impetus of its spring the plunger is then forced upward, camming the ball radially outward into this en-

(*Concluded on Page* 134)



Simple ball latch enables booster mechanism to store mechanical energy until tripped by counter

These Metals Gain Strength at

SUB-ZERO TEMPERATURES

...yet do not become Brittle!

MECHANICAL PROPERTIES AT LOW TEMPERATURES

MATERIAL	Condition	Temperature °F.	Yield Strength (0.20% offset) psi.	Tensile Strength psi.	Elongation in 2 in. per cent	Reduction of Area per cent	Hardness Rockwell C	Charpy Impact Strength ft.-lb.
MONEL	Cold-drawn	Room	93,700	103,800	19.0	71.0	19	181
	Cold-drawn	−110	100,850	117,450	21.8	70.2	25	178
"K" MONEL	Cold-drawn age-hardened	Room	125,900	157,300	15.5	37.4	33	27
	Cold-drawn age-hardened	−110	134,600	171,550	17.3	41.1	36	27
INCONEL	Annealed	Room	36,800	93,800	37.3	64.1	82B	130
	Annealed	−110	42,400	106,450	39.8	64.0	87B	134
	Cold-drawn†	Room	147,700	152,100	7.0	49.3	31	54
	Cold-drawn†	−110	154,900	163,900	9.8	51.2	36	60
NICKEL	Cold-drawn	Room	97,400	103,400	16.3	66.9	19	204
	Cold-drawn	−110	101,800	112,300	21.5	60.9	22	215

† 50 per cent reduction in cross-sectional area by cold drawing.

plus **CORROSION RESISTANCE** . . . together with strength, hardness, toughness —

plus **EXTRA HARDNESS** . . . comparable to heat-treated alloy steel; age hardenable, non-magnetic —

plus **HEAT RESISTANCE** . . . with retention of high degree of strength. Resists oxidation, high corrosion resistance —

plus **NON-CONTAMINATION** . . . protects product purity; offers good electrical conductivity —

plus **MACHINABILITY** *and* **EXTRA HARDNESS** . . . free cutting, age hardenable, non-magnetic —

plus **RESILIENCE** . . . age hardenable, for exceptional spring properties, magnetic, good electrical conductivity —

plus **MACHINABILITY** . . . for high speed production in automatic screw machines —

plus **HARDNESS** *in* **CASTINGS** . . . anti-seizing and non-galling —

Selecting the right metal for a given application is today more important than ever. How drastically the possibilities narrow down is exemplified by *sub-zero* requirements.

At sub-zero temperatures, for example, most ferrous metals become brittle as their strength increases. INCO Nickel Alloys also increase in strength and hardness . . . but they retain room-temperature ductility and toughness as measured by tensile and impact tests (*see table above*).

Two INCO Nickel Alloys, "K" Monel and "KR" Monel retain another important property, non-magnetism . . . magnetic transformation point of these age-hardened alloys being −150° F.

A new technical insert, "Mechanical Properties at Low Temperatures" and the booklet "Individualized INCO Nickel Alloys" offer useful information. For copies of each write to:

THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N. Y.

FIRST THINGS FIRST

With the Nation at war, supplies of Monel, Nickel and Nickel Alloys are needed for our armed forces. All efforts must now be aimed toward victory. In the meantime The International Nickel Company will continue to issue information which it is believed will be of interest to metal users who are concerned with the war needs of today and the peace-time progress of the future.

★ ★ ★ ★ **INCO NICKEL ALLOYS** ★ ★ ★ ★

MONEL • "K" MONEL • "S" MONEL • "R" MONEL • "KR" MONEL • INCONEL • NICKEL • "Z" NICKEL

Sheet . . . Strip . . . Rod . . . Tubing . . . Wire . . . Castings

Gear Specialties

SPURS—SPIRALS—BEVELS—WORM GEARING
(14 to 96 D.P.)

With considerable experience and exceptional facilities for the manufacture of high precision Small Gears, our manufacturing capacity is now heavily burdened with National Defense work, and we naturally feel pardonable pride in the importance and quality of our contributions to the Program.

While this very essential work takes precedence, we are keenly conscious of our *duty* to *established* customers; their needs must command our continued earnest efforts. Under such circumstances, we hope new inquirers will understand our inability to give their wants the consideration they would ordinarily receive.

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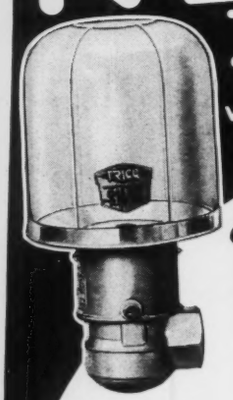
KEEP THE WHEELS TURNING
WITH—
TRICO
REG. U. S. PAT. OFF.
Automatic
OILERS
MODERN STREAMLINED UNBREAKABLE



- Low Cost
- Added Prestige
- Easy Installation
- Extra Sales Feature

TRICO Oilers give that modern, up-to-the-minute appearance . . . eliminate guesswork . . . give improved machine performance and assure proper oiling after your product is in service.

WRITE FOR BULLETINS

Many sizes and types Available

TRICO FUSE MFG. CO. Milwaukee, Wis.

(*Concluded from Page* 128)

larged space. The plunger continues its upward motion raising the push-rod under the counter lever. At the same time the firing spring is fully compressed. This is illustrated at the left.

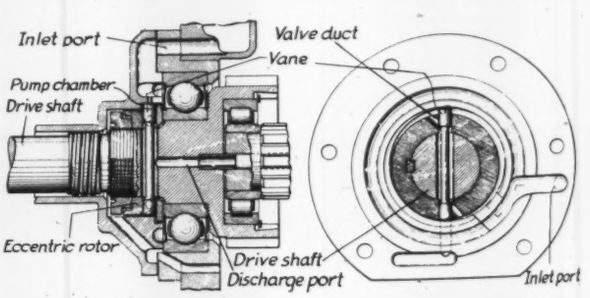
When the pre-selected amount of material has been registered by the counter, the counter lever is actuated downward. This motion forces the plunger downward compressing its light spring. As the enlarged portion of the plunger passes the ball check or latch, the camming action of the counter-bored section of the body forces the ball latch radially inward. The piston is thus freed from restraint and, under the impetus of the firing spring, it is forced instantly downward to the position shown in the right-hand illustration.

Incorporates Built-In Controls

INCREASED loads on transmission mechanisms emphasize the necessity of adequate lubrication. Pumps for supplying lubricants to these transmissions must be so valved as to prevent any back flow of oil and, in order to avoid greatly increasing the temperature of the oil, must not agitate it excessively or create too high pressures. A pump satisfying these requirements has been patented by the Mack Mfg. Corp.

As illustrated, the pump is of the positive displacement vane type. As the driveshaft rotates the pump rotor, the vane is induced to reciprocate in the bore of the rotor due to its eccentricity with the pump chamber. In the right-hand view the rotation of the rotor is in a counterclockwise direction. As the lower end of the vane rotates upward to the right, oil trapped in the pump chamber is forced through the valve duct adjacent the lower end of the vane. During this pumping action the upper end of the vane is displaced downward by the wall of the chamber so that its valve duct is closed off. Fluid pumped into the bore concentric with the reduced portion of the vane is forced through the discharge port into the lubricating system.

The action of the large section of the vane in closing off the valve ducts at the conclusion of their delivery cycle, effectively prevents the backing up of oil through the pump. Fluid pressure delivered by the pump as well as the quantity of fluid delivered may be varied by adjusting the angular relationship of the inlet port to the eccentric rotor.



Positive displacement rotary pump incorporates design features which serve as an automatic check-valve preventing backing up of lubricants

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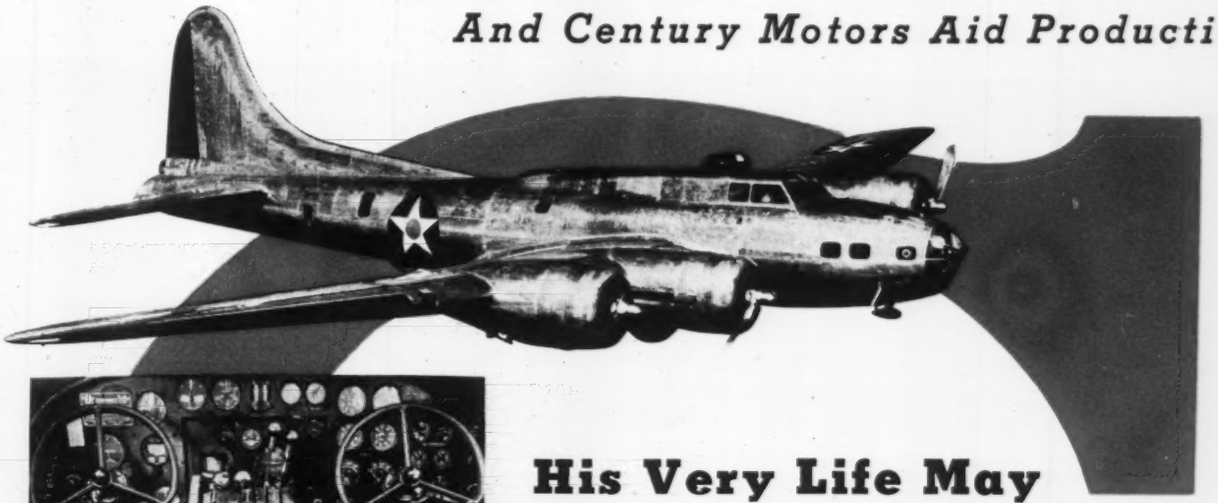

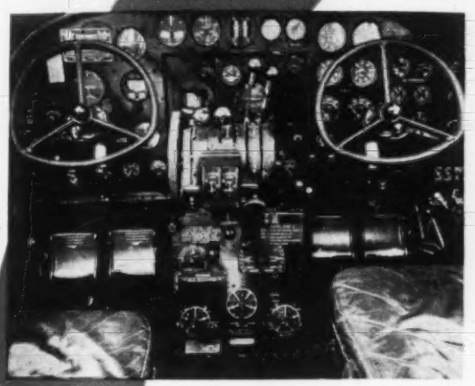

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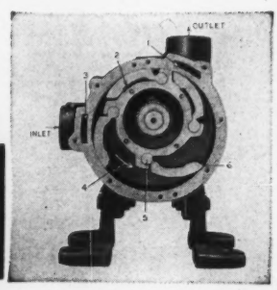

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High Pressure Vessels

(*Continued from Page* 81)

Considering the case where P is a tensile load, the value of U is a maximum for $r = a$. Equating this strain energy to the allowable value $S_w^2/2E$, by Equation g,

$$\frac{S_w}{p_i} = \left(\frac{R^2}{1-R^2}\right) \times \sqrt{3(1-2m)+2(1-2m)L_1+L_1^2+\frac{2(1+m)}{R^4}} \quad \ldots\ldots (7)$$

where $R = a/b$ and $L_1 = P/\pi a^2 p_i$.

For a value of $m = .25$, Equation 7 becomes

$$\left(\frac{S_w}{p_i}\right) = \left(\frac{R^2}{1-R^2}\right)\sqrt{1.5+L_1+L_1^2+\frac{2.5}{R^4}} \quad \ldots\ldots (7a)$$

The variation between the load-stress ratio, S_w/p_i, and the load ratio L_1 is shown in *Fig.* 8*a* for different values of the dimension ratio $R = a/b$. For particular values of the loads and working stress the x and y ordinates in the graph are determined and by interpolation the required dimension ratio $R = a/b$ is selected. To cover all possible load ratios the value of $L_1 = P/\pi a^2 p_i$ is replaced in Equation 7*a* and this equation can then be written

$$\frac{S_w \pi a^2}{P} = \left(\frac{R^2}{1-R^2}\right)\sqrt{1.5(L_1')^2+L_1'+1+\frac{2.5(L_1')^2}{R^4}}$$

where

$$L_1' = \frac{1}{L_1} = \frac{\pi a^2 p_i}{P}$$

Equation 7*b* is plotted in Fig. 8*a* in a manner similar to Equation 7*a*. To show the effect of the variation in Poisson's ratio, equations similar to 7*a* and 7*b* were determined for a value of $m = .35$ and plotted as shown in *Fig.* 8*b*.

There are many industrial applications in the power, oil refining and chemical industries in which piping subjected to high internal pressures is used. In addition to stresses from internal pressure, stresses in such piping are caused by thermal expansion. Bending and twisting moments may also be produced, as well as transverse shearing forces. The stresses ordinarily considered, however, are only those due to the bending and twisting moments and those due to internal pressure.[2]. *Fig.* 9 represents diagrammatically a length of thick-walled piping subject to these loads. The stresses produced by the loads shown are a shear stress S_s due to the twisting moment M_t, a longitudinal stress S_L produced by the internal pressure

[2] Regarding current practice see *Design of Piping Systems*, published by M. W. Kellogg Company, New York, 1941.

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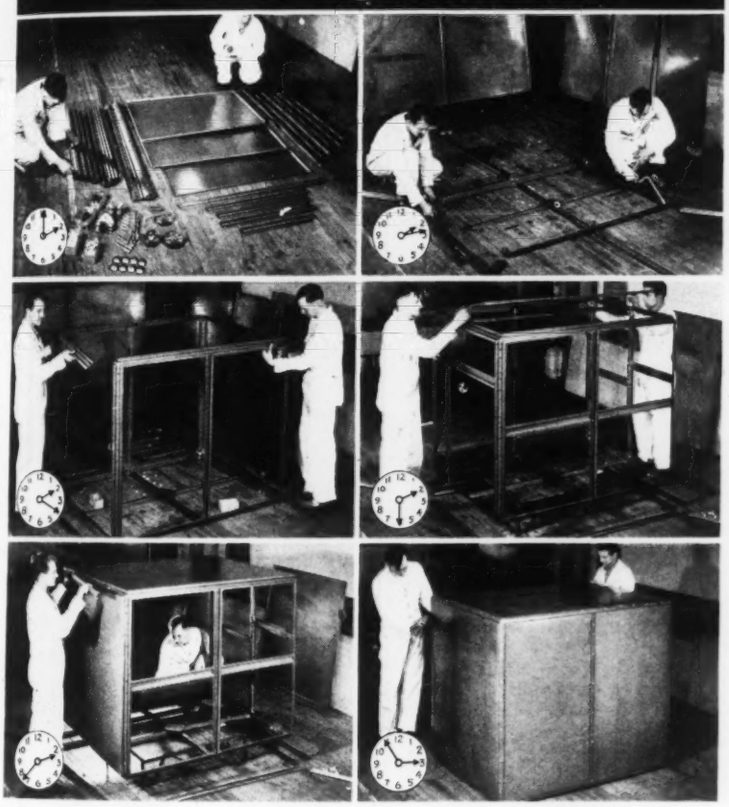

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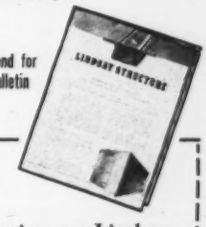

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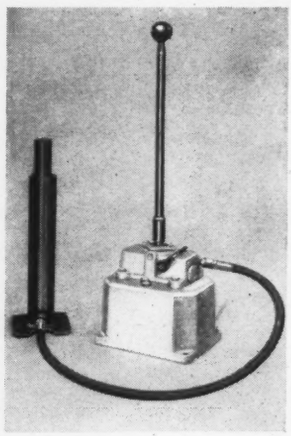

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p_i and bending moment M, a circumferential stress S_c and a radial stress S_1 due to the internal pressure p_i.

The values of the stresses for an element A at a distance r are

$$\left.\begin{aligned} S_1 &= k_1 p_i\left(1-\frac{b^2}{r^2}\right), \quad S_c = k_1 p_i\left(1+\frac{b^2}{r^2}\right) \\ S_L &= k_1 p_i + 2k_3 M r, \qquad S_s = k_3 M \cdot r \end{aligned}\right\} \quad \ldots\ldots (h)$$

where

$$k_1 = \frac{a^2}{b^2-a^2} \quad \text{and} \quad k_3 = \frac{2}{\pi(b^4-a^4)} \quad \ldots\ldots (i)$$

The values of the principal stresses S_2 and S_3 for this element, in terms of the stress components S_c, S_L and S_s, are

$$\left.\begin{matrix} S_2 \\ S_3 \end{matrix}\right\} = \frac{S_L+S_c}{2} \pm \frac{1}{2}\sqrt{(S_L-S_c)^2+4S_s^2} \quad \ldots\ldots (j)$$

Placing the values of the stresses S_2 and S_3 as given by Equation j in Equation 1, the strain energy for the element A becomes

$$U = \frac{1}{2E}\Big[S_L^2 - 2mS_LS_c + S_c^2 + 2(1+m)S_s^2 + S_1^2 - 2mS_1(S_L+S_c)\Big] \quad \ldots\ldots (k)$$

Placing the values of the stresses in terms of the loads from Equations h in Equation k, the strain energy becomes

$$U = \frac{k_1^2}{2E}\left[3p_i^2(1-2m) + \frac{8p_i r(1-2m)M}{\pi a^2(b^2+a^2)} + \left(\frac{2r}{\pi(b^2+a^2)a^2}\right)^2\left(4M^2+2(1+m)M_t^2\right) + 2p_i^2(1+m)\left(\frac{b}{r}\right)^2\right] \quad \ldots\ldots (l)$$

By rearranging the terms in Equation l,

$$U = \frac{1}{2E}\left(\frac{p_iR^2}{1-R^2}\right)^2\left[3(1-2m)+8(1-2m)\left(\frac{L_1Rx}{1+R}\right) + \left(4L_1^2+2(1+m)L_2^2\right)\left(\frac{4R^2x^2}{(1+R)^2}\right) - \frac{2(1+m)}{x^4}\right] \quad (8)$$

where $x = r/b$, $R = a/b$, $L_1 = M/\pi p_i a^3$, $L_2 = M_t/\pi p_i a^3$.

For an average value of $m = .3$, Equation 8 becomes

$$U = \frac{1}{2E}\left(\frac{p_iR^2}{1-R^2}\right)^2\left[1.2+\left(\frac{3.2L_1R}{1+R}\right)x + \left(4L_1^2+2.6L_2^2\right)\left(\frac{4R^2}{(1-R)^2}\right)x^2 + \frac{2.6}{x^4}\right] \quad \ldots\ldots (8a)$$

The position of the critical element where failure would occur is defined as in the other examples where the value of the strain energy U is a maximum. Theoretically, the value of x for maximum U can be determined by calculus. That is, Equa-

Designing Molded Plastics Parts: RIBS BOSSES FILLETS

From The Engineering Files Of One Plastics Avenue

Ribs, bosses and fillets are often essential to molded plastics parts. The following general factors should be considered in design specifications:

1. Design ribs with ample section and sufficient draft or taper. High bosses and all ribs should have at least 5° taper and generous radii at top and base.
2. Large otherwise unsupported surfaces should be designed with ribs to provide adequate mechanical strength and minimize warpage. A safety factor of 5 or better is recommended.
3. Fillets increase strength of mold and of molded part, prevent lodging of compound in corners with resulting premature cure.
4. Mounting bosses should project at least 1/64 in. beyond other projections on molded part.
5. Ribs act as runners or feeders and may be used to flow materials to isolated bosses or projections.

RIBS are used to provide strength and facilitate flow of material. Ribs may be used on one or both surfaces. When ribs are used on inside surface of light-colored material, decorative ribbing on outer surface may be necessary to conceal lines or shadows.

For urea parts ribs should be as short as possible and of uniform thickness, approximating thickness of main section.

BOSSES are used for mounting or assembly. They should be located in corners whenever practicable.

When four bosses are used for mounting molded parts it is usually necessary to grind their top surfaces flat. Three bosses are preferable as they do not require this finishing operation. For small bosses the height should not be more than 2 times the diameter.

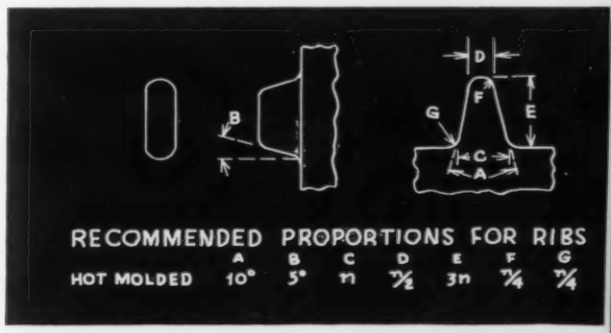
High bosses which must be formed by deep recesses in the upper mold member should be avoided because of difficulty of machining mold. High bosses tend to trap gas, decreasing density and strength of molded part. For bosses in side walls of light-colored parts decorative fluting on outer face will conceal any shadows or flow lines.

FILLETS (or radii) at base of ribs or bosses facilitate flow of compound and eliminate sharp corners which concentrate stresses in molded part.

Fillets on inside ribs or bosses minimize shadows or flow lines which may appear on outer surfaces.

Fillets frequently reduce mold costs, improve appearance of part, and eliminate dust traps which make part difficult to clean.

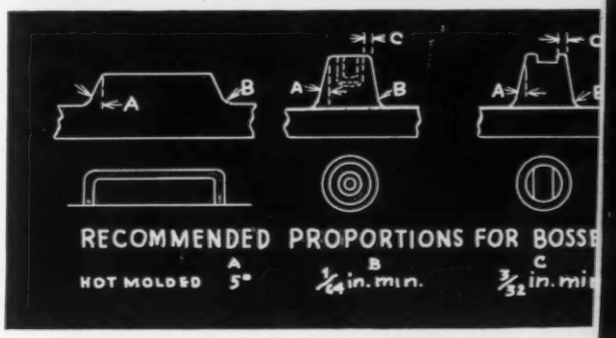
Molded parts should have at least 1/32 in. radius for all corners, with the exception of flash lines which should be sharp. Cold molded parts should have 1/16 in. minimum radii.



RECOMMENDED PROPORTIONS FOR RIBS

	A	B	C	D	E	F	G
HOT MOLDED	10°	5°	n	n/2	3n	n/4	n/4

TYPICAL APPLICATION—Refrigerator control part in which ribs provide strength, bosses simplify mounting and assembly, and fillets improve moldability and appearance.



RECOMMENDED PROPORTIONS FOR BOSSES

	A	B	C
HOT MOLDED	5°	1/64 in. min.	3/32 in. min.

ADDITIONAL FACTS Proper design of ribs and bosses improves serviceability of molded parts and contributes to economical manufacture. G.E. offers a consulting engineering service based on experience, successful production and complete molding facilities.

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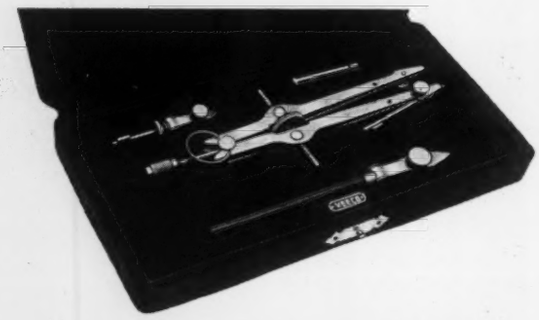

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tion 8 can be differentiated with respect to x and the derivative dU/dx placed equal to zero. The resulting equation for x is to the sixth power of x. This complicates the problem considerably. Another difficulty is due to the fact that the maximum value of U will depend upon the relative values of the load ratios L_1 and L_2. It is necessary, therefore, to use a long procedure for determining the maximum value of U by considering all possible values of x. The possible combinations of the load ratios L_1 and L_2, as well as variations in R, must also be considered if all cases are to be covered. The procedure used is as follows:

1. Select a value of the dimension ratio R and place in Equation 8*a*
2. Select particular values of load ratios L_1 and L_2 and substitute in Equation 8*a*
3. Considering the various possible values of x, determine the maximum value of the strain energy $U_{(max)} = (1/2E)(p_i^2 C)$ where $C =$ a constant for a particular case.
4. Equate the strain energy $U_{(max)}$ to the allowable value $S_w^2/2E$ and solve for S_w/p_i. That is,

$$\left(\frac{S_w}{p_i}\right) = \sqrt{C} \qquad (9)$$

where C is determined for each combination of values considering the load values L_1 and L_2 and the dimension ratio $R = a/b$.

The values of the pressure-stress ratio, S_w/p_i, for different values of the load ratios L_1 and L_2 and various values of the dimension ratio $R = a/b$ are plotted in *Figs.* 10 to 17. These diagrams cover all possible combinations of loads. To do this the values of L_1 and L_2 from 0 to 1 as well as $1/L_1 = L_1'$ and $1/L_2 = L_2'$ from 0 to 1 are considered. That is, for values of L_1 and L_2 greater than 1, Equation 8*a* can be written. . . . . .

$$U = \frac{1}{2E}\left(\frac{p_i R^2}{1-R^2}\right)^2\left[1.2+\left(\frac{3.2R}{1+R}\right)\left(\frac{x}{L_1'}\right)+\left(\frac{4}{(L_1')^2}+\frac{2.6}{(L_2')^2}\right)\left(\frac{4R^2x^2}{(1+R)^2}\right)+\frac{2.6}{x^4}\right] \qquad (8b)$$

where $L_1' = 1/L_1$ and $L'_2 = 1/L_2$.

An examination of *Figs.* 10 to 17 shows that these diagrams can be used for design purposes. This is done by selecting first the diagrams closest to the load ratio L_2. Knowing the values of the load ratio L_1 and the stress-pressure ratio S_w/p_i, a point on the graph is defined. By interpolation, the required value of the dimension ratio $R = a/b$ can then be found and the wall thickness selected.

There are other stresses in high-pressure equipment that must be considered sometimes, such as local bending stresses and stresses due to temperature changes. In applications using very high temperatures the presence of creep will change the stress distribution produced and the creep deformations will also be large in certain cases unless stress values are reduced.

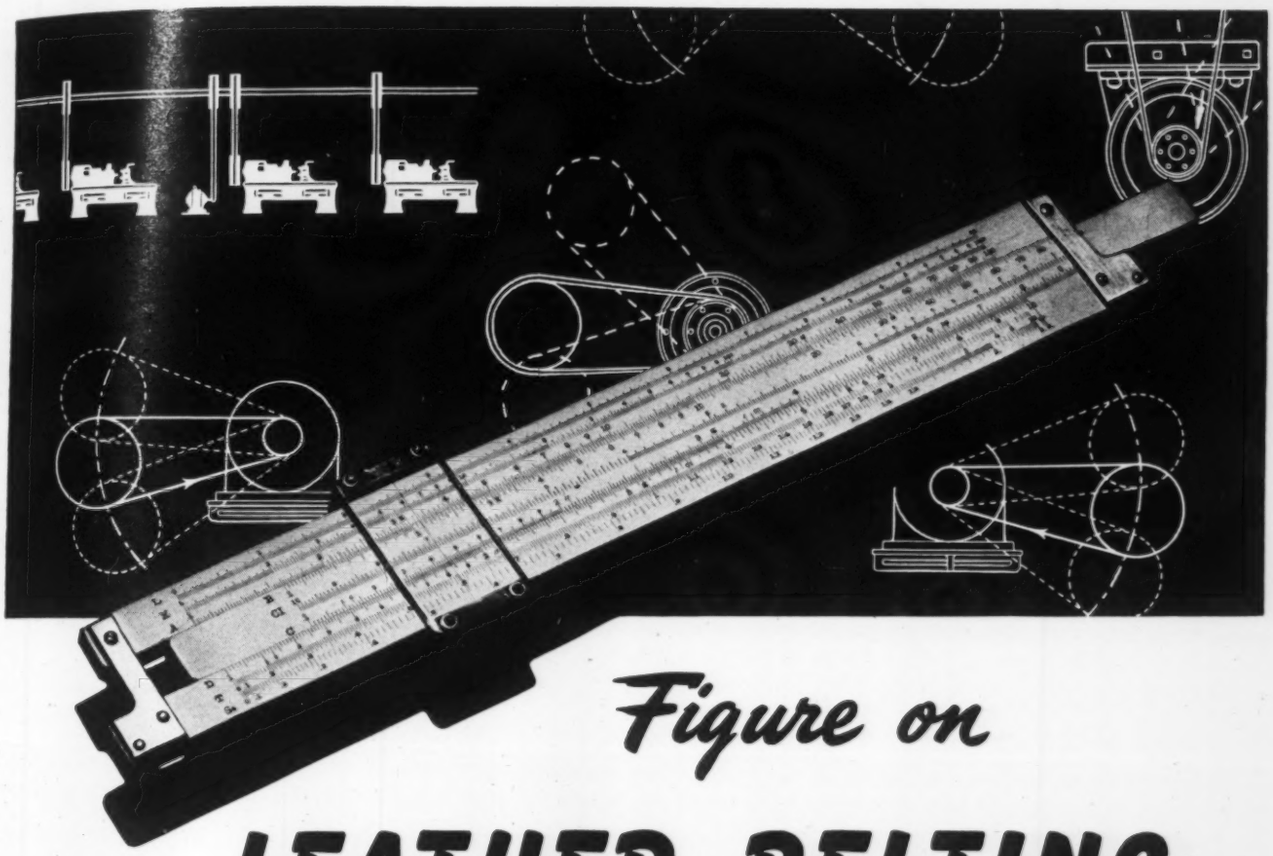

Figure on

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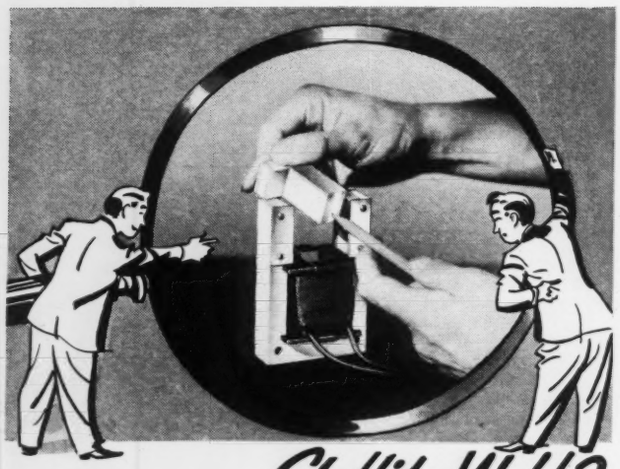

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Selecting Fittings

(*Continued from Page* 60)

movement to absorb vibration. An application of this type of fitting in the fuel line of a power lawn mower is shown in *Fig.* 7. Where vibrations or pressures beyond the capacity of this joint are encountered a flexible tube is desirable.

Another design using a neoprene sleeve is designed to have a strength sufficient to develop the full burst strength of 52-S aluminum alloy tubing conforming to Army-Navy standards. In this joint, tubing is flared at an angle of 12 degrees with a small locking ring assembled immediately behind the flare. The resilient sleeve has metal bushings at each end to confine the synthetic rubber. Under tightening of the nut, the compression sleeve conforms to the outer wall of the tube and the angular faces of the body and nut.

Flexible Tubing Needed for Large Movement

When major movements are required of the tubing or vibration is of large amplitude, the action is too severe for semirigid tubing such as brass or Bundy steel tubing. Flexible tubing then is needed. Rubber, fabric covered neoprene, Hicar or other synthetic hose may be used. Some types have steel wire wound under the fabric cover to provide protection against kinking. A typical fitting is shown in *Fig.* 8. Body is screwed over end of hose and an insert or grommet corresponding to a nut is then screwed into hose, tightly bonding it between threads of insert and body. Assembly is locked together by further screwing insert into mating threads in body. This will hold the indicated bursting pressure of the hose for which it is designed.

Another style resembles the conventional compression fitting in that it utilizes a ferrule. The body is different, however, employing an integral grommet over which the hose slips. This supplies the necessary support for the compression action of the nut on the ferrule. Other styles include permanent hose connections of various types and involve the use of a forming or crimping tool to lock the hose on the grommet.

Interesting among fittings for special applications is the snap-type coupling shown in sectional view in *Fig.* 9. Suitable for portable tools such as spray guns and pneumatic drills, it facilitates operation from multiple stations or for quick change of attachments. Insertion of the plug into a socket simultaneously opens a valve and locks the coupling. This action forces locking pins down inclined holes, compressing collar on socket head. At the same time, end of plug opens valve and seats itself against a neoprene washer. To open joint, collar is pushed forward to disengage locking pins. As the plug leaves the socket, the valve seats on the back side of the neoprene washer. Washer is readily replaceable by unscrewing socket head. Joint has been tested with pressures up to 11,000 pounds per

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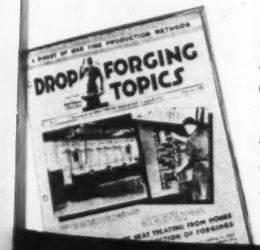
CHECK THESE 7 ADVANTAGES OF FORGINGS NOW

THIS MESSAGE has a single purpose, namely, to help you obtain the utmost of every advantage that forgings offer, so that you may produce more armaments at a faster rate.

The war is being decided by the extent to which you, and others who use forgings in armaments, conserve critical materials, and lessen the time it takes for machining and finishing. Get every one in your plant who is responsible for obtaining and finishing forgings to check these seven advantages.

Consult a forging engineer about how to get the fullest measure of benefits from the forgings you are using. No one source is so well qualified to help you as the management executives and forging engineers connected with your source of supply. They are giving all they've got to step up production in their shops, and in your plants.



Drop Forging Topics contains technical information for design engineers, machine shop executives, metallurgists and other technicians who are striving to step up production of armaments. If you are not already receiving Drop Forging Topics, you are invited to enlist your name. It's free.

1 FORGINGS CONSERVE METAL: Strength is a primary quality advantage of forgings. The metal bulk of many parts may be reduced because maximum tensile and torsional strength is obtainable in forgings through controlled grain flow and distribution of metal.

2 FORGINGS LESSEN SCRAP: In forgings it is possible to obtain uniformity of physical properties in the exact degree desired. Practically no rejections result. Heat treating forgings is a straight-forward production procedure, controllable at all times.

3 FORGINGS CONSERVE METAL BY WEIGHT REDUCTION OF PARTS: Reduction of dead weight is a common result of using forged parts because forging produces maximum strength in lighter sectional thicknesses, thereby permitting the use of lighter weight parts.

4 FORGINGS FACILITATE RAPID ASSEMBLY THROUGH WELDING ADAPTABILITY: Forgings provide a welding adaptability of widest range for fabricating complicated parts from two or more forgings.

5 FORGINGS REQUIRE LESS TIME TO MACHINE AND FINISH: Forgings are shaped in closed dies and require a minimum of machining or finishing because there is no bulk of excess metal to remove, and freedom from concealed defects avoids loss from rejections.

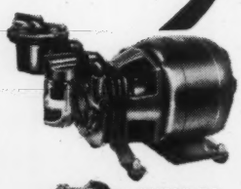
6 FORGINGS REDUCE ACCIDENTS TO MEN AND MACHINES: Freedom from concealed defects is an outstanding characteristic of forgings that underlies the greater margin of safety that forgings afford for men, machines and material.

7 FORGINGS CAN TAKE IT: By the forging process, stamina is achieved through concentration of grain structure and fiber formation at points of greatest shock and strain. Forgings provide high fatigue resistance which underlies dependable performance, and continuous operation over longer periods of use.

...ROP FORGING ASSOCIATION

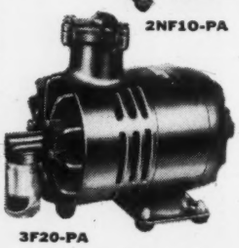
...5 Hanna Building • Cleveland, Ohio

Where Space is LIMITED
USE GAST Integral ROTARY COMPRESSORS



● On machines where space for the Compressor is limited, the problem is solved by using these Gast Integral Rotary Compressors—the most compactly built units on the market. Compactness and light weight are obtained by making the Compressor an integral part of the driving motor. This integral design also affords two extra advantages: — *additional economy* because there is no need to buy a separate mounting base or driving mechanism—and *unusual smoothness* due to the utilization of the heavy motor frame as a mounting base. These units embody all of the other superior performance features of Gast units such as the Gast Rotary Design, Self-Adjusting Shaft Seal, and Automatic Take-Up that compensates for wear.

2NF10-PA



3F20-PA

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Containing complete descriptions, specifications, engineering data and performance tables for all Gast Vacuum Pumps as well as Compressors. Address Gast Mfg. Corporation, 107 Hinkley St., Benton Harbor, Michigan.

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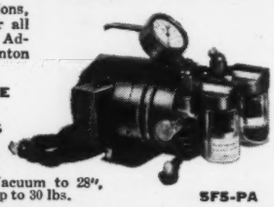
COMPLETE LINE INCLUDES

12 sizes Air Pumps ½ to 23 c.f.m., Vacuum to 28", Pressures up to 30 lbs.



5F5-PA

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514 NORTH WATER STREET

square inch. The higher the pressure the better the seal against the synthetic washer. Forward side of joint is vented to atmosphere to prevent piston action on plug during assembly and disassembly. The joint is satisfactory for swivel service although wear on seal may cause frequent replacement.

Often rigid piping is desired for applications involving major movement such as shown in *Fig.* 10. Used with steam for heating the movable platens, the joints are capable of 360-degree swivel move-

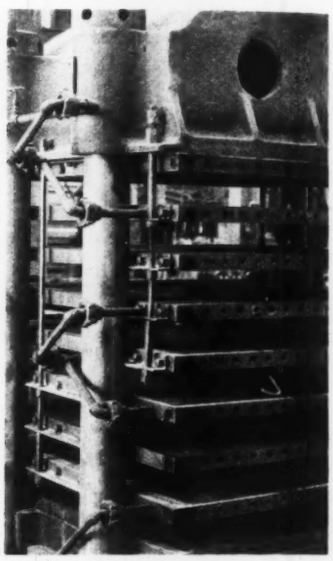

Fig. 10 — Swivel joints for piping on steam-heated press

ment with sufficient side flex to take care of misalignment. Joint has a spring-loaded socket with a synthetic washer sealing against a spherical surface on the swivel member. It is capable of operating with steam at 650 degrees Fahr. and 300 pounds pressure. For hydraulic service, 3500 pounds per square inch is within the range of the fitting. Another style, the flexible ball joint, seals with two opposing washers against the surface of the ball.

For supplying steam, gas or other fluids from a stationary pipe to a revolving member, a rotating type is needed. Free movement in all directions including axial are desirable to reduce possibility of strain and wear. In a recently improved design, provision is made for axial movement by a ball bearing with an axially extended outer race. This obviates the necessity of a flange on the joint side of the rotating member. Being outside the flow stream, adequate lubrication is provided.

With the wide variety of fittings available and the results of exhaustive tests for both pressure and vibration to indicate the capacity of each type of fitting, the selection for a particular application should not involve any considerable amount of investigation to assure joint dependability.

Co-operation of the following companies in supplying information and illustrations used in this article is gratefully acknowledged: Barco Mfg. Co., *Fig.* 10; Caterpillar Tractor Co., *Fig.* 3; The Dole Valve Co.; the Hansen Mfg. Co., *Fig.* 9; Hays Mfg. Co.; Imperial Brass Mfg. Co., *Fig.* 7; Raybould Coupling Co.; The Weatherhead Co., *Figs.* 1, 2, 4, 5, 8; Worthington Mower Co., *Fig.* 6.

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WITH SINGLE-ROW BALL BEARINGS

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PRECISION ROLLER BEARINGS

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Write for the Catalog. Let our engineers work with you.

Their solid cylindrical rollers provide maximum contact area, giving larger load and shock-absorbing capacity than any other single-row bearing of like dimensions. Thus, when NORMA-HOFFMANN PRECISION ROLLER BEARINGS are used in place of ball bearings, a greater factor of safety is provided, together with added life, particularly under vibration and overload. PRECISION qualities in workmanship and materials adapt them alike for both low and high speeds.

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their "Bucket Design" looks good to me.
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BRANCH OFFICES IN ALL PRINCIPAL CITIES

Business and Sales Briefs

BECAUSE of expansion in the field of industrial electronic control, General Electric Co. has organized an electronic control division, with Allen E. Bailey Jr. and William D. Cockrell as manager of sales and engineer respectively.

♦

Previously vice president in charge of Westinghouse Electric & Mfg. Co. merchandising division, B. W. Clark will replace Ralph Kelly as vice president in charge of sales of the company. Mr. Kelly has resigned to become executive vice president of the Baldwin Locomotive Works.

♦

Decentralization of certain government departments from Washington has necessitated removal of the Chicago sales and engineering offices of Lord Mfg. Co. to 520 North Michigan avenue. George Frutche, formerly in the sales engineering department at the home office, has been transferred to Chicago as field engineer.

♦

Appointment of J. D. Young as manager of pump sales has been announced by G. B. Tuthill, president of the Tuthill Pump Co., Chicago.

♦

Decision by the United States Court, Buffalo, N. Y., in the case of New Wrinkle Inc., Dayton, owner of patents on wrinkle finishes, has been reached upholding validity and infringement of these basic patents. After the Court examined defenses, it found wrinkle finishes broadly new as covered by the patents in suit.

♦

According to an announcement by George R. Fink, president, Great Lakes Steel Corp., all daily and monthly world's records for blast furnace production were broken by the company's Zug Island furnace, with a straight ore burden production for the month of 43,478 tons and the final day production of 1608 tons. The previous figure was that of 41,782 tons for one month, set a few weeks ago in Pittsburgh.

♦

Vice president of American Locomotive Co., New York, and in charge of munitions and miscellaneous sales, W. E. Corrigan has assumed additional duties as head of diesel engine sales.

♦

Crocker-Wheeler Electric Mfg. Co., Ampere, N. J., has named J. B. Colesworthy its Los Angeles district sales representative, with headquarters at 1709 West Eighth street. He formerly was associated with the Los Angeles sales organization of Westinghouse Electric & Mfg. Co.

♦

At the annual meeting of Oil Burner institute in New York recently, C. E. Lewis, general sales manager, Delco Appliance division of General Motors Sales Corp., Rochester, N. Y., was elected president.

♦

Ferro Enamel Corp., Cleveland, has modified its trademark for war purposes, from the former check and circle to the new one of a circle with the word "Victory" in it.

♦

Removal of its Chicago office to new and larger quarters at 624-630 West Adams street, has been

(*Concluded on Page* 152)

AS APPLIED TO LODGE & SHIPLEY No. 3A DUOMATIC LATHE ★ ★ ★

This Lodge and Shipley Duomatic Lathe is set up for rough turning the ogive after nosing operation on 155-mm. shells. The headstock is equipped with a "LOGAN" Model "R" Double Acting Rotating Type Air Cylinder to supply gripping pressure to the "LOGAN" 3-Jaw Compensating Chuck. The tailstock is equipped with a "LOGAN" Model "A" Double Acting Non-Rotating Type Air Cylinder. In addition, this Lodge and Shipley Lathe is equipped with a "LOGAN" Reducing Valve, Lubricator and Pressure Gauge Unit and a "LOGAN" Model "H" Foot Control Valve. This "LOGAN" Air Equipment provides rapid, positive action and rigid support of the work. "LOGAN" Representatives and "LOGAN" Engineers will be glad to make recommendations on your problems.

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Manufacturers of Air and Hydraulic Devices, Chucks, Cylinders, Valves, Presses and Accessories

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AMERIPOL*
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The smooth, glossy finish given Miller Ameripol* hydraulic seals, gaskets and rings is not just a matter of appearance. Because of this high finish, abrasion is reduced and service life lengthened.

Every one a precision product manufactured by precision methods, Miller Ameripol seals can be made to aircraft tolerances. Highly resistant to oils, Ameripol compounds limit oil absorption to 6%.

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MILLER RUBBER COMPANY, Inc., Akron, Ohio
(A Division of The B. F. Goodrich Company)
"Engineers in Rubber"

(*Concluded from Page* 146)

announced by The Allen-Bradley Co., Milwaukee. John McC. Price continues in charge as district manager.

♦

Formerly general sales manager of Taylor Wharton Iron & Steel Co., Highbridge, N. J., J. A. Krugler has been appointed vice president in charge of sales.

♦

Employed by General Electric Co. since 1910, H. C. Clement has been named assistant to the New York district manager. Since 1923 Mr. Clement was represetative in the sales division of the central station department, at which post he remained until his present appointment.

♦

Clarence W. Coe and Everett W. Bickford have been named division managers of the Fort Wayne and Taunton plants, respectively, for General Electric Co.'s plastics department.

♦

Election of Ralph H. McOuat as president of Romec Pump Co., Elyria, O., has been announced. Mr. McOuat was formerly vice president of Pump Engineering Service Corp.

♦

John J. Fitzpatrick has been elected a vice president of the Armstrong Cork Co., Lancaster, Pa. He has been associated with the company since 1911.

♦

After having served as general manager of the Texas division of Monsanto Chemical Co., St. Louis, for some time, Osborne Bezanson was elected a vice president of the company.

♦

Announcement has been made by the Thiokol Corp. of its purchase of two large sections of the former Murray Rubber Co. plant in Trenton, N. J. The Thiokol company will use the newly acquired units in the manufacture of special synthetic rubber latex to go into production of war equipment.

♦

Appointment of J. B. Weisel as advisor to J. B. Davis, Chief of the Protective and Technical Coating section, War Production Board, in charge of nitrocellulose and ethyl cellulose, has been announced. Mr. Wiesel is director of sales of cellulose products department of Hercules Powder Co.

♦

Offices in New York of the American Insulator Corp. have been moved from 101 Park avenue to 40 Lexington avenue.

♦

Sponsored by Plastics Industries Technical Institute, evening study forums in key industrial cities will be conducted by men with plastics knowledge and experience. Forums requiring attendance two evenings each week for twenty weeks are already under way in Chicago, Detroit and Newark, N. J. J. C. Kazimier, product development engineer, Chicago Molded Products Corp., heads the Chicago forum located at 221 North La Salle street. N. J. Rakas, director of plastics development for Chrysler Engineering, is in charge of the Detroit group at 728 Boulevard building, Woodward avenue at Grand. The forum at Newark, N. J., is under the direction of Dr. John P. Trickey, assistant technical director at the institute, and is located at 5 Commerce street. All forums are under the direct supervision of John Delmonte, Technical Director of Plastics institute, in Los Angeles. Study forums in other industrial centers are now being planned.

INDUSTRY SHOOTS PRODUCTION MINUTES

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★ save metal
★ save cost
★ improve quality
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Micromatic Hones range from sizes for bores .303" to 25½" in diameter—from ¼" to 900" long. They generate geometrical and dimensional accuracy, uniform size and any desired surface finish with minimum removal of stock.

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Meetings and Expositions

May 10-12—

American Gear Manufacturers association. Twenty-sixth annual convention to be held at Hotel Hershey, Hershey, Pa. J. C. McQuiston, 602 Shields building, Wilkinsburg, Pa., is secretary.

May 11-12—

Association of Iron and Steel Engineers. Annual spring conference to be held at Royal Connaught hotel, Hamilton, Ont., Canada. J. L. Miller, 1010 Empire building, Pittsburgh, is secretary.

May 11-13—

American Institute of Chemical Engineers. Thirty-fourth semiannual meeting to be held at the Statler hotel, Boston. S. L. Tyler, 50 East Forty-first street, New York, is secretary.

May 19-20—

National Metal Trades association. Forty-fourth annual convention to be held at Biltmore hotel, New York. Harry S. Flynn, Room 1021, 122 South Michigan avenue, Chicago, is secretary.

May 25-28—

Heating, Piping and Air Conditioning Contractors National association. Annual meeting to be held at the Schroeder hotel, Milwaukee. Joseph C. Fitts, 1250 Sixth avenue, New York, is secretary.

May 31-June 1-2—

American Society of Refrigerating Engineers. Semiannual meeting to be held at the Skytop club, Skytop, Pa. David L. Fiske, 50 West Fortieth street, New York, is secretary.

May 31-June 5—

Society of Automotive Engineers Inc. Annual summer meeting to be held at The Greenbrier, White Sulphur Springs, W. Va. John A. C. Warner, 29 West Thirty-ninth street, is secretary.

June 8-11—

American Society of Mechanical Engineers. Semiannual meeting to be held at Hotel Statler, Cleveland. C. E. Davies, 29 West Thirty-ninth street, New York, is secretary.

June 17-19—

American Society of Mechanical Engineers. Oil and Gas Power division meeting to be held in Peoria, Ill. C. E. Davies, 29 West Thirty-ninth street, New York, is secretary.

June 22-26—

American Institute of Electrical Engineers. Summer convention to be held at the Drake hotel, Chicago. H. H. Henline, 33 West Thirty-ninth street, New York, is national secretary.

June 22-26—

American Society for Testing Materials. Annual meeting to be held at Chalfonte-Haddon hall, Atlantic City. R. E. Hess, 260 South Broad street, Philadelphia, is assistant secretary.

June 28-July 1—

American Society of Agricultural Engineers. Annual meeting to be held at Schroeder hotel, Milwaukee. Raymond Olney, Box 229, St. Joseph, Mich., is secretary.

"All-Out" Effort

TAKES ON NEW MEANING IN 1942

TODAY'S EMERGENCY finds BCA well prepared for "all-out" effort. Since it was established in 1897, BCA has refused to let business drift along "as usual." By close application . . . by working hard and constantly in association with equipment manufacturers . . . BCA contributed materially to the development of ball bearings for many types of vehicles and machinery.

In the past, BCA's "all-out" effort produced such marked improvements as the Composition Seal Bearing . . . the Prelubricated Clutch Bearing and the "Burr Relief" Shaft Bearing. Today, far greater effort is devoted to the armed forces and the industries vital to victory. Tomorrow, it will provide America with still better radial . . . angular contact . . . and thrust ball bearings.

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